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EDITORIAL NOTES.

FOR reasons of economy and for the convenience of the printers, each contribution to the GEOLOGICAL MAGAZINE is set up in type only a short time before actual publication. It is therefore most desirable that proofs should be returned by authors as speedily as possible. Each number is supposed to appear on the first of the month, but lengthened retention of proofs by authors has of late often led to serious delay. For example, one proof for the July number was not received by the Editor till 3rd July; hence the very late appearance of that particular number. The Editor also desires to ask contributors to return to him in every case the order-form for separate copies enclosed with proofs of original papers, blank or cancelled if none are required. If this form is not returned at all, or sent direct to the printers, some unnecessary correspondence is bound to ensue. Unless there is any special reason to the contrary, manuscripts or originals of plates and figures need not be returned with proofs; much money is wasted in this way, especially as postage is often insufficiently prepaid. The addressed envelopes sent out with proofs should always be used for return, as it is possible to ensure that a particular type of envelope shall be forwarded when the Editor is away from Cambridge, as frequently happens.

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W. HEFFER & SONS, LTD., Publishers, Cambridge, have in the press a volume entitled *Cements and Artificial Stones: A Descriptive Catalogue of the Specimens in the Sedgwick Museum, Cambridge*, by the late John Watson, Hon. M.A. (Cantab.), F.G.S.; edited by R. H. Rastall, Sc.D. This book, like the works of the same author on *Building Stones* and *Marbles*, is much more than a mere catalogue of specimens. The student will find in it a brief history of the origin and development of the cement industry, as well as instructive notes on the manufacture and uses of the various kinds of cement, concrete, and artificial stone, which are exhibited in the Economic Department of the Sedgwick Museum of Geology, at Cambridge. Professor J. E. Marr, Sc.D., F.R.S., contributes a preface, in which he states that the book should be found useful by all who are interested in the subject.

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THE National Academy of Sciences in Washington has awarded the gold B. G. Elliot Medal to Dr. Othenio Abel, Professor of Palæobiology in the University of Vienna, for his memoir entitled "Methoden der palæobiologischen Forschung" published in Abderhalden's *Handbuch der biologischen Arbeitsmethoden*.

ORIGINAL ARTICLES.

Wegener's Displacement Theory.

By Philip Lake, M.A., F.G.S.

In examining ideas so novel as those of Wegener [1] it is not easy to avoid bias. A moving continent is as strange to us as a moving earth was to our ancestors, and we may be as prejudiced as they were. On the other hand, if continents have moved many former difficulties disappear, and we may be tempted to forget the difficulties of the theory itself and the imperfection of the evidence. Those who study the distribution of animals and plants must be especially subject to this temptation, and it will be instructive to note how far they agree in their demands upon the moving continents.

Wegener himself does not assist his reader to form an impartial judgment. Whatever his own attitude may have been originally, in his book he is not seeking truth ; he is advocating a cause, and is blind to every fact and argument that tells against it. Nevertheless, he is a skilful advocate and presents an interesting case. Perhaps he may claim that if his readers cannot approach the subject without prejudice, he can hardly be expected to perform the functions of a judge. He does not make the attempt.

It might be useful to trace the gradual change in outlook that has made the motion of a continent conceivable, but it would take too long. Wegener mentions Wettstein, Pickering, F. B. Taylor, and Schwarz as having actually suggested movement, though their ideas are different from his.[2]

In the last part of *Das Antlitz der Erde* Suess imagines the earth to consist of an outer envelope composed chiefly of the lighter and more acid rocks, an inner envelope of basic rock, and an interior core of still heavier material. He calls the first the Sal, the second the Sima, and the third the Nife.

Wegener accepts the terminology of Suess, except that he follows Pfeffer in writing Sial instead of Sal. But he thinks that the Sal does not cover the globe completely. It now exists in independent patches, which float in the heavier Sima. Because of their smaller density they rise above the surface of the Sima and constitute the land-masses of the globe, while the Sima itself forms the floor of the oceans.

In this there is nothing essentially new. It has long been known that plumb-line and pendulum observations point to a deficiency of density beneath the major elevations of the globe and an excess

[1] A. Wegener, *Die Entstehung der Kontinente und Ozeane*, 2nd ed., Braunschweig, 1920.

[2] Wettstein's notions seem to have been developed in a book published at Zürich in 1880. The other references are as follows : W. H. Pickering, *Journ. of Geol.*, vol. xv, 1907, p. 23 ; F. B. Taylor, *Bull. Geol. Soc. Amer.*, vol. xxi, 1910, p. 179 ; E. H. L. Schwarz, *Geog. Journ.*, vol. xl, 1912, p. 294.

beneath the oceans. Some sixty years ago Archdeacon Pratt[1] concluded that the "density of the crust beneath the mountains must be less than that below the plains, and still less than that below the ocean-bed", and subsequent work has tended to confirm his conclusion. Lord Kelvin suggested that the differences in density may be due to differences in the composition of the original crust formed when the molten globe consolidated. But Airy's explanation[2] comes nearer to Wegener's conception. He assumes a lighter crust resting upon a heavier substratum. The latter is supposed to have some fluidity, but the fluidity may be very imperfect—he thinks "it may even be little more than that degree of yielding which (as is well-known to miners) shows itself by changes in the floors of subterraneous chambers at a great depth where their width exceeds 20 or 30 feet". He proves that the crust, even if it be a hundred miles in thickness, cannot of itself support a plateau a hundred miles broad and two miles high. But since such plateaux exist there must be a corresponding downward protuberance of the lighter material into the heavy stratum beneath. They are, in fact, supported by flotation.

Airy's explanation was not universally accepted. The observed phenomena of tides and of precession require an earth that is as rigid as a ball of steel or glass of the same size, and it was thought that such rigidity excludes even the small degree of plasticity assumed by Airy. But many experiments, now well-known, have shown that under sufficient pressure substances as rigid as steel may flow, without becoming liquid in the ordinary sense. Rigidity and elasticity are not qualities belonging solely to the substances concerned. They depend also upon the forces acting and the length of time for which they act. Perhaps the oldest illustration of the point is embodied in the proverb, "A bow long bent at last waxeth weak." A small, but long-continued stress may produce a permanent change of shape, while a greater stress acting for a shorter period may leave no lasting effect. The rigidity and elasticity required by the phenomena of tides, earthquake-waves, etc., may be compatible with the plasticity demanded by modern theories of isostasy, or even by the theory of Wegener. The forces concerned are different.

Up to this point the views of Wegener were foreshadowed long ago. That the floor of the oceans may consist of rock more basic than the land-masses is believed by some, and that the lighter land-masses dip into a heavier substratum is very generally conceded. But Wegener imagines that these lighter masses have moved laterally, and are still moving, and this is a very different matter. There is the force of gravity to press them downwards into the Sima, but there is no known force comparable in magnitude with this to move them sideways. It is possible, however, that a

[1] *Figure of the Earth*, 3rd ed., 1865, p. 134.
[2] *Phil. Trans.*, vol. cxlv, 1855, p. 101.

much smaller force may be sufficient, for the movements imagined are imperceptibly slow and the time allowed indefinitely long. Wegener believes that the predominant movements have been towards the Equator and towards the west, and he offers some suggestions to account for this, but he does not profess that the problem has been solved. His contention is that whether the cause is known or not the movements have actually taken place.

Much of his evidence is superficial. He supposes, as others have supposed, that South America was connected with the Antarctic continent through Graham Land. As the whole mass was pushed westward through the resistant Sima, the narrow isthmus bent and broke, and the fragments trailing behind formed the island arc of South Georgia, the Sandwich Group, and the South Orkneys.

Similarly, he attributes the elbow of the Malay Peninsula and the eastward curve of the Malay Islands to the resistance of the Sima. In connexion with this example it is interesting to notice a suggestion made by Osmond Fisher.[1] He is considering Sir George Darwin's idea that the Pacific depression may be the scar left where the moon separated from the earth, and he frankly admits that he is indulging in a far-fetched speculation. He thinks it possible, however, that the islands of this part of the world may be fragments of the broken crust which have floated slowly towards the cavity left when the moon was thrown off.[2] But this belongs to an early period of the earth's existence. He never supposed that such movements were taking place now, and he did not consider the geological history of the islands in question, a matter which Wegener also entirely ignores.

But Wegener has evidence more impressive than this. According to him, if we take the masses of Sal as they exist to-day and allow movement, they may be fitted together like the pieces of a puzzle, and when this is done correctly the tectonic structures of each piece are continued into the piece which has been fitted to it. If this can be proved, few geologists will doubt the truth of his conclusions.

It is necessary, first, to determine the present shapes of the existing masses, and it should be remembered that he is not concerned with the division between land and water, but with the division between Sal and Sima. Here he is inconsistent. According to his own idea the masses of Sal float in the Sima and the surface of the Sima forms the floor of the ocean. The boundary of the Sal should therefore be drawn at the foot of the continental slope, where the continental masses begin to rise from the ocean-floor. Instead, he takes the edge of the continental shelf as the margin of the Sal, though, as he says, he allows himself a certain freedom. This can only be correct if the surface of the Sima rises several thousands of feet as it approaches the masses of Sal, and he gives no reason for such a rise.

[1] *Physics of the Earth's Crust*, 2nd ed., 1889, p. 339.

[2] Pickering's idea (*Journ. of Geol.*, vol. xv, p. 23) is similar to this, but he imagines much more extensive effects. He supposes the separation of Africa from South America to be due to the same cause.

Having obtained the outlines of the masses of Sal he now endeavours to fit them together. Maps, owing to their inevitable distortion, cannot be employed. He uses a globe and transfers the outlines to tracing paper cut and slashed to fit it. The method is unsatisfactory, as anyone who has tried it will admit; and it is easier to obtain an accurate representation of the mass of Sal by applying a sheet of plasticine to the globe and cutting it into the shape required.

With the liberty that he has allowed himself Wegener finds that some of the masses fit together sufficiently well; but he is not satisfied. He considers what the shapes must have been before the great movements of the Tertiary era, and he proceeds to flatten out the folds of the Alps, the Himalayas, and other modern mountain ranges. A little more freedom is now unavoidable, for even in the best-known cases estimates of the effect vary widely, and in most no estimate of any value can be made. He does not think that the flattening out of the Alpine folds would obliterate the Mediterranean, but he imagines that the unfolding of the Himalayas would produce an elongated Indian Peninsula extending through nearly sixty degrees of the earth's surface. He does not enter into details.

He now fits Africa to South America and brings them both into contact with Antarctica. Australia also is joined to the Antarctic Continent, and Madagascar and the extremity of his elongated India are wedged between Australia and Africa. In the north, Greenland, eastern Canada, and north-western Europe come together, but a wide space is left between the rest of North America on the west and southern Europe and northern Africa on the east.

These are the principal features in his reconstruction of the Sal as it existed at the close of the Carboniferous period, after the Hercynian folding. It brings the fragments of Gondwana Land into the neighbourhood of the South Pole, and thus he accounts for the Permo-Carboniferous glacial deposits of those fragments; but he has made it more difficult than ever to explain the existence of the Gondwana flora in northern Russia.

Undoubtedly it is the fitting of Africa to South America that makes the most general appeal. The correspondence in their coast-lines has often been noticed, and vague suggestions have been made that they may have come apart from one another. The correspondence is not so precise as casual observation indicates, for the angles of the corners are not the same. If South America be fitted into the Gulf of Guinea, either its eastern or its northern coast must separate rather widely from the coast of Africa. It is the eastern coast that fits most closely, and the fit is as good as could reasonably be expected. But other coincidences, presumably accidental, may be found upon the globe. If we take the Australian mass—excluding the greater part of New Guinea, which is geologically distinct—and place it in the Arabian Sea, the fit is nearly as good, and in some respects more remarkable. The north-western concavity of the

mass fits the convexity of Somali-land, its north-eastern border comes very near the Western Ghats, while its northern portion, where ignorance of the geology compels "a certain freedom", may fill the northern part of the Sea. Wegener, it is true, includes New Guinea as part of the Australian mass in Carboniferous times, but he has not considered its geology.

Such coincidences have little value without other evidence to support them, and in the case of the Atlantic Wegener produces further evidence, which deserves examination in some detail.

There are coal-bearing beds in Spitsbergen and similar beds of the same age in north-eastern Greenland. Therefore he brings Spitsbergen up to Greenland. There are Precambrian intrusives at Cape Farewell and Precambrian intrusives in Labrador, so he closes up the space between. It should be remembered that he closes gaps by bringing the two edges together and not by bridging.

In the Hebrides and northern Scotland, he says, the strike of the ancient gneiss is from north-east to south-west; in Labrador it is from east to west. When the two masses are brought together the two directions fall into line and become continuous. Farther south, the Caledonian folds of Scotland and North Ireland join the supposed Caledonian folds of Newfoundland, and the Armorican folds of South Ireland and Brittany unite with the folds of corresponding age in Nova Scotia and are thus connected with the Appalachians.

Then comes the space to which reference has already been made. What happens to the folds of the Spanish Peninsula, where they now run out to sea, he does not say; but it is against his principles to imagine that they can be continued in a block which has sunk beneath the ocean. He suggests, rather vaguely, that the northern border of Spain may have been joined to the western border of France—continental shelf to continental shelf, not coast to coast—and that the Peninsula has since turned as on a hinge situated in the neighbourhood of Biarritz. But this does not greatly help.

Farther south, according to him, the entire African continent consists of a very old folded mass of gneiss in which two different strikes prevail. In the Sudan, and as far as the Cameroons, a north-east strike predominates; south of the Cameroons the direction is from north to south. In South America, he says, there is a similar change of strike. In eastern Guiana and as far as Cape St. Roque the strike is from east to west; south of Cape St. Roque it is parallel to the eastern coast. As he represents them, when Africa and South America are joined, these directions fall into line at the junction, as if produced when the two masses were united.

Finally, in South Africa the Zwartebergen is a Carboniferous folded range running from east to west. It is true that near the western coast an arm, the Cederbergen, turns up towards the north; but this is clearly, he says, a local branch. In South America, south of Buenos Aires, there is a folded range of similar age and structure.

When Africa and South America are joined, again the folds fall into line.

All this is striking; but, to say the least, some of the statements are rash. The existence of similar deposits in Spitsbergen and north-east Greenland is not surprising, even on the old hypothesis. The presence of Precambrian intrusives at two localities is not strong evidence for bringing those localities together. Wegener asserts that in the gneiss of the Hebrides and northern Scotland the strike is north-east—south-west. The Survey Memoir on the North-west Highlands gives the prevalent trend as west-north-west—east-south-east or east—west. If the asserted direction is evidence in favour of the union suggested, the actual direction must be evidence against it.

Whether the Caledonian system of folding has any real representative in North America is still a matter of opinion; but if west and east were in contact when the folding and thrusting took place, the intensity of the movement must have diminished with great abruptness in the west. It is probable that there is some connexion between the Appalachian and the Armorican folds, but the fact that the two ends when brought together should coincide is not remarkable. It is a more significant coincidence that a great circle drawn along the Appalachian folds leads into and along the Armorican folds, a fact which suggests, though it does not prove, that they formed a continuous system, and that the visible portions are in their original relative positions.

Wegener's statement that the strike of the crystalline rocks in the Sudan is from north-east to south-west is an instance of the manner in which he ignores any observations that do not agree with his views. It is not borne out even in the map by Lemoine,[1] which he reproduces. He admits that the map does not show his point very well, but says that it was drawn for other purposes. No doubt he is right. Lemoine was collecting facts and not supporting hypotheses. If we refer, by way of example, to Falconer's account of Northern Nigeria,[2] in which the strikes observed at many localities are recorded, we find that the direction varies, but, in the majority of cases, it lies within a few degrees of the meridian. Either the strike is too variable to support Wegener's generalization, or the change takes place several hundreds of miles from the position he assigns to it.

On the other hand, the assertion that south of the Cameroons the strike is north to south is an example of the way in which Wegener draws wide conclusions from the most slender evidence, if the evidence is what he wants. Lemoine is more cautious. He says that the records hitherto published are very scanty, but they suggest that the zones of folding are sensibly parallel to the coast and hence approximately north—south.

[1] P. Lemoine, *Afrique occidentale. Handbuch d. Reg. Geol.*, p. 57.

[2] J. D. Falconer, *The Geology and Geography of Northern Nigeria*, London, 1911.

It would take too long to discuss the remainder of Wegener's assertions, but these examples are sufficient to show their value. South African geologists[1] have not considered it so obvious as he does that the Cederbergen Mountains are merely a local branch of the Zwarteberg ranges, or that the east to west folds of the latter were ever continued beyond their junction with the former. If they were it would be curious that upon the western coast, directly in the path that these folds would take, the Table Mountain Sandstone lies nearly flat.

Even on the assumption that all Wegener's tectonic statements can be justified, we should still have to consider whether the structures on the two sides of the Atlantic can be joined to one another. In his reconstruction they fit very well, but he acknowledges that he has pressed Newfoundland and Labrador strongly towards the north-west and has turned the former through an angle of about 30 degrees. The motion of Newfoundland may be admitted as consistent with the hypothesis; but if, in addition to moving the masses of Sal, we are also allowed to mould them as we will, the coincidences that we deduce become evidence of imaginative powers, not of former realities.

To test the amount of distortion which is involved in Wegener's reconstructions the most accurate method is to use some form of triangular compasses,[2] the three points of which may be set upon three points of the globe and then transferred, without altering their relative positions, to any other part. But it is easy to obtain a good idea of the distortion by simpler means. Upon a globe stretch a thread from Valentia, in Ireland, to Cape Town. It will cut off a little corner of the Gulf of Guinea. It will be convenient to use white thread and to mark upon it the positions of the three places referred to. Now place the Valentia mark upon St. John's, in Newfoundland, and stretch the thread so that it cuts Cape St. Roque. The mark for the Gulf of Guinea will lie north of Cape St. Roque and the Cape Town mark will be in the middle of the Atlantic, well over 1,200 geographical miles from the province of Buenos Aires, where the continuation of the Zwartebergen is supposed to be. To be exact, we should first push Newfoundland against the American coast, which will make matters a little worse, and should take points at the edge of the continental shelf instead of Valentia and St. John's, which will improve them. But it is clear that if the masses are kept rigid and are made to touch in the north, the Zwartebergen cannot be brought within 1,200 miles of the range in Buenos Aires.

[1] Du Toit (*S. African Journ. of Sci.*, vol. xviii, 1921, p. 120) accepts Wegener's views, but does not discuss this point. Schwarz's theory (*Geog. Journ.*, vol. xl, 1912, p. 294) does not require any direct connexion between the South African ranges and those of Buenos Aires.

[2] The ordinary triangular compasses of the draughtsman are of very limited use upon a globe. In a recent letter to *Nature*, vol. cx, p. 77, I have suggested an easily constructed form which is fairly convenient in use. More convenient forms may be devised, but their construction is a little more difficult.

It is evident, then, that Wegener's reconstruction implies much more than fracturing of the masses of Sal. They must have altered their shapes. No one knows how much they have altered, or which of them have altered; and to deduce their original forms would require a much greater knowledge of their geological structure than we possess, and a much more critical examination than Wegener has bestowed upon the question.

It will be useful now to summarize the evidence with regard to the Atlantic. If east and west are to be brought together both in the north and in the south, there must be great distortion. One side or the other, or both, must be plastic. If they are moulded so as to fit, as Wegener fits them, the following points may be noticed. If we accept Wegener's statement about the gneiss of Labrador, then we know, from the Memoir on the North-west Highlands, that there must be a sudden change of strike at the junction. At the junction, too, the violent Caledonian movements of the British Isles must suddenly die down into the less conspicuous movements of the same age in Newfoundland. The Armorican folds fit very well.

Again, if we accept Wegener's statements about South America, and assume that both in Africa and South America there is a definite line where a change of strike occurs, then the position of that line on one side of the junction lies hundreds of miles away from its position on the other. Lastly, in South Africa the folds bend northward near the western coast, and there is no evidence that they were ever continued farther west. It may be noted in passing that the ranges in Buenos Aires have not yet been closely examined.

We may now turn to a few general considerations. Apart altogether from mountain-building movements, due to crumpling, it is certain that large areas of the Sal have sunk beneath the sea and have risen again, not only once but many times. If we admit the presence of deep-sea deposits, their surfaces must have reached the level of the Sima. We know, at least, that they sank below the hundred-fathom line, which Wegener takes as the general boundary between Sal and Sima. Some of these movements have been oscillations, one portion of the mass rising while another fell. Others, such as the Cenomanian transgression, have been almost world-wide in their effects. The former, perhaps, may be ascribed to tilting of the blocks. The sunken areas would then be subjected to an upward hydrostatic pressure, and if the Sal is as plastic as Wegener's reconstruction requires, it is not easy to understand why it did not bend instead of sinking so deeply into the Sima as it must have done. The widespread movements are still more difficult to explain. Some cause is required which would press all the masses more deeply into the Sima; and it must have been a temporary cause, for they rose again.

A problem which Wegener scarcely touches is the formation of the separate masses of Sal. He imagines that at one time the Sal formed a thin skin completely covering the globe. The sea was then

continuous, and there was no land. Thus he explains the supposed uniformity of the Cambrian and other early faunas; but he forgets that beneath the Torridonian deposits of Scotland a Precambrian landscape is preserved which shows clear evidence of strong sub-aerial erosion.

At a later date the covering of Sal was broken and the fragments piled upon one another like ice-floes in a thawing river. But he offers no suggestion as to the cause of the breaking or the cause of the piling. In effect his theory really begins with the masses of Sal already constituted, and arranged as in his reconstruction. It begins in fact at the close of the Carboniferous period.

It would be interesting to discuss the evidence brought forward by Wegener and his coadjutor Koch to show that Greenland has moved perceptibly during the last hundred years, but this paper is already too long. They assume an accuracy of observation which is unexampled in exploratory survey. It is indeed a curious circumstance that for many of his most remarkable points Wegener depends upon exploratory survey of one sort or another. Where our knowledge is more precise the evidence is much less striking.

In conclusion, it may be said that Wegener has performed a valuable service by drawing attention to the fact that land-masses may have moved relatively to one another. He has not proved that they actually have moved, and still less has he shown that they have moved in the way that he imagines. He has suggested much, he has proved nothing.

The Nomenclature of the Spilitic Suite. Part I: The Keratophyric Rocks.

By Alfred Kingsley Wells, M.Sc., F.G.S.

I. Introduction.

THE petrologist who attempts the systematic investigation of igneous rocks is unfortunately too familiar with the difficulty of naming the rocks examined. The discovery of a border-line type necessitates a choice of two alternatives: either the introduction of a new name to a science already overburdened with such, or the widening of the definition of the nearest established type to include the newly described rock. The decision is no easy one to make, especially if the petrographer is young and eager for the transient fame won by the discovery of something new. In such a case the temptation to create a new name is very strong. As a result, both student and teacher spend tedious hours in trying to discover differences between rocks bearing different names, differences which, however, have been magnified out of all proportion to their importance as diagnostic characters.

The second alternative is but little more desirable, the obvious drawback being that the undue widening of a definition destroys the

signification of the original name, and the individuality of the type rock. It must be conceded that this is the ultimate fate of the majority of rock names as at present constituted: almost every investigation results in the discovery of rocks differing by little or by much from established types, it adds one or more links to the chains connecting the latter, until finally a gradation from one to the other is found to exist.

It is thus useful and necessary occasionally to look back in order to see how the significance of particular rock names may have changed, and to what extent original definitions must be modified to conform to increased knowledge arising from more recent discoveries.

Within recent years the Spilitic Suite of rocks has received almost general recognition as a suite distinct from others in respect of peculiarities of chemical and mineral composition, and in the mode of formation of its members. This distinct individuality is most marked in the case of the spilites, the basic members of the suite, but is apparent also in the intermediate and acid members, the keratophyres and quartz-keratophyres respectively. In spite of interesting problems concerning the petrogenesis of these rocks, they receive but scanty attention in our standard textbooks. Thus Hatch,[1] when describing hypabyssal felsites is content to insert "keratophyre" in brackets after the name soda-felsite. Harker[2] is hardly more explicit, though mention is made of the fact that "ceratophyres" are sometimes intrusive, sometimes extrusive, and consist mainly of soda felspars, with little or no quartz—a definition which can scarcely be described as explicit. So the inquirer has to search through contemporary geological literature to discover the exact meaning of this name. The most useful account of these rocks is that of Cox,[3] in a short paper read before the British Association in 1913, an account which has not yet been amplified, however, although it contains many interesting suggestions. Apart from this, much useful information can be gleaned from the published accounts of the igneous rocks of various parts of Wales, Devon and Cornwall, and Scotland. Among other British writers Cox, Dewey and Flett, Hatch, Jevons, Teall, and Thomas have used the word, but by no means always with the same meaning. The marked difference of opinion concerning the application of the names "keratophyre" and "spilite" has led the writer to attempt this review.

II. Historical.

As long ago as 1874 Gümbel[4] introduced the name keratophyre, which he applied to rocks sometimes undoubtedly intrusive in the

[1] Hatch, *Text Book of Petrology*, part i, Igneous Rocks, 1913, p. 223.
[2] Harker, *Petrology for Students*, 5th ed., p. 117.
[3] Cox, *Rep. Brit. Assoc. Birmingham*, 1913, p. 496.
[4] Gümbel, *Die paläolithischen Eruptivgesteine der Fichtelgebirge*, 1884, p. 45.

Cambrian strata of the Fichtelgebirge. Later, Lossen [1] showed that similar rocks occur in the Middle Devonian strata of the Harz. In commenting upon the chemical analyses of these, the original keratophyres, Teall [2] emphasizes the wide range of silica percentage, varying from 50 to 70%, and the large proportion of alkali felspar, calculation showing the presence of from 74 to 92%. Considerable variation in the soda : potash ratio is another noteworthy feature of these rocks, sometimes the former, sometimes the latter being in excess. It is evident, therefore, that the name keratophyre was given to an ill-defined group of rocks varying widely in chemical and mineral composition as well as in mode of occurrence.

It is interesting to note that Teall, after stating that keratophyres had not then (in 1888) been discovered in this country, suggested their probable occurrence in the West of England. This prediction has proved true, as keratophyric rocks have been found to be abundant in the Newton Abbot district and to "characterize every horizon at which volcanic activity is evident",[3] although they are rare in other parts of Devon and Cornwall.

The first discovery of keratophyric rocks was recorded by Hatch, who found them among the Ordovician soda-felsites (lavas), of Wicklow.[4] His paper contains the statement that Rosenbusch had foretold their discovery among the Welsh rocks. Within recent years this prediction also has proved true. Thomas on Skomer Island, Cox at Abereiddy Bay, and Part in the Prescelly Mountains have described keratophyres from these several different parts of South Wales, while Cox and the writer have claimed as keratophyres lavas occurring on two horizons in Merioneth.

In classifying the Skomer Island Volcanic Series, Thomas divides certain of the intermediate sodic lavas into two groups, (*a*) soda trachytes, and (*b*) keratophyres. It is stated that a family connexion exists between the two,[5] which grade one into the other. What, then, is the basis on which the division is made? The following points of difference are emphasized: the less perfect development of flow structure, the greater amount of chlorite and granular sphene, and the better developed vesicular structure in keratophyres. These differences are comparative only, and it is doubtful if any of them is of sufficient importance to justify the use of two names for rocks which seem so much alike. That one name would serve for both is evidently the opinion of some, as the suggestion has been made that both should be termed keratophyres, following the Continental usage of the word. Here, then, are two conflicting opinions; the first that "keratophyre" is far too comprehensive

[1] Lossen, *Jahrb. k. preuss. Geol. Landesanst. fur* 1884 (1885), p. 21.
[2] Teall, *British Petrography*, 1888, p. 369.
[3] Flett, "Geol. of the Country around Newton Abbot": *Mem. Geol. Surv.*, 1913, p. 57.
[4] Hatch, GEOL. MAG., 1889, p. 70.
[5] Thomas, *Quart. Journ. Geol. Soc.*, vol. lxvii, 1911, p. 193.

a term, and one needing restriction,[1] the second that the definition should be widened to include all intermediate albite-rich rocks, irrespective of their mode of occurrence.[2]

III. Intrusive Keratophyric Rocks.

With regard to the latter point, the utilization of one name for both lava and hypabyssal equivalent is not without precedent. Indeed, the tendency is growing to place micro-structure before mode of occurrence as the diagnostic feature determining the nomenclature of the rock. Thus "dolerite" and "basalt" are frequently used in a sense which ignores the mode of occurrence of the rock. When such is the case is it not desirable to prefix the rock name with "extrusive" or "intrusive", as the case may be? It seems to the writer that a greater degree of accuracy is to be attained by using the lava name for extrusive rocks only, and introducing compound terms where necessary for specimens having textures other than normal. Thus "doleritic basalt" would signify an extrusive rock with the mineral composition and field characters of basalt, but the texture of dolerite. With the rocks under consideration the case is not so simple, as no distinctive name exists for intrusive keratophyric rocks, other than the lava name.

Those workers who prefer to restrict "keratophyre" to lavas only, have made use of various names for the corresponding intrusive rocks, among them being "albite-porphyry", introduced in 1884 by Heddle for a porphyritic rock of unique composition composed only of albite, and occurring on Beinn Braghaid, in Sutherlandshire.[3]

Again, "soda-granite-porphyry" has been utilized by the officers of the Survey on at least two occasions; for a porphyritic rock intrusive into pillow lavas (spilites) at Porthallow Cove in the Lizard District,[4] and for a more acid, but closely similar rock, also intrusive into pillow lavas at Tavvallich.[5] Synonymous with the above name is "quartz-albite porphyry", used for the columnar intrusive felsite of Ynys Bery near the Pembrokeshire coast.[6] In addition to these self-explanatory terms, place-names have occasionally been coined for the designation of intrusive keratophyric rocks; thus, hirnantite,[7] the even less euphonious beschtauite, is briefly dismissed by Holmes in his recent work, the *Nomenclature of Petrology*, as a "soda rich variety of quartz porphyry (= quartz-keratophyre)".

Before considering an alternative suggestion, the possibility of using the name "lime-bostonite" (maenaite) for these rocks claims

[1] Thomas, *Quart. Journ. Geol. Soc.*, vol. lxvii, 1911, p. 214.
[2] Cox, *Rep. Brit. Assoc. Birmingham*, 1913, p. 496; also *Quart. Journ. Geol. Soc.*, vol. lxii, 1915, p. 316.
[3] Heddle, *Min. Mag.*, 1884, p. 141.
[4] "Geology of the Lizard and Meneage": *Mem. Geol. Surv.*, 1912, p. 186.
[5] "Geology of Knapdale, etc.": *Mem. Geol. Surv.*, 1911, pp. 93 and 94.
[6] *Geology of the South Wales Coalfield*, part ii, Milford, p. 41
[7] *Proc. Liverpool Geol. Soc.*, 1915, p. 79.

our attention. Lime-bostonite (maenaite) was applied by Brögger to certain leucocratic intrusives in the Gran district of South Norway.[1] The same name was chosen by Elsden for the chemically similar, but genetically dissimilar felsite at Abercastle, in Pembrokeshire, then regarded as a normal intrusive rock.[2] At a later date this name was applied to a similar, definitely intrusive rock in the Kilbride Peninsula.[3] Reynolds and Gardiner, in referring to their choice of this name, remarked upon the striking similarity of the Kilbride rock to the keratophyres of Skomer Island, but explain that they preferred to use "lime-bostonite", as "British authors seem to confine the name keratophyre to lavas". During the re-examination of the Abercastle rock, it became evident that the percentage of normative anorthite had been considerably over-estimated, and that the felspar of the rock was almost pure albite.[4] Thus, "lime-bostonite" as applied to these rocks appears to be a misnomer.

IV. Genetic Considerations.

The descriptive terms mentioned above are undoubtedly useful; they indicate not only the mineral contents, but also the texture of the rocks. But they fail to take account of the petrogenesis. They do not suggest the genetic relationship of these with other members of the Spilitic Suite. But genetic considerations must not be ignored. There is little doubt that upon the latter will be built up the classifications of the future. Thus Harker quite definitely states that . . . "a natural classification must have regard to the mutual associations of rocks as well as to their descriptive characters."[5] He evidently regards as the ideal a scheme of classification based on the genetic relationships of different rocks. Various authors, since the writing of the *Natural History of Igneous Rocks*, have duly emphasized the same fact, none more emphatically than Crook,[6] whose most significant phrases are quoted and amplified by Holmes in the opening chapter of *Petrographic Methods*. This ideal scheme is admittedly unattainable in the present state of our knowledge, but a grouping together of rocks genetically related must be regarded as a step in the right direction, while the inclusion under one name of rocks of different parentage is a retrograde movement, and one likely to cause confusion.

Dewey and Flett tentatively suggested the fact, afterwards definitely stated by Cox, that keratophyric rocks, intrusive as well as extrusive, belong to the Spilitic Suite.[7] The constant association

[1] Brögger, *Quart. Journ. Geol. Soc.*, vol. l, 1894, p. 23.
[2] Elsden, *Quart. Journ. Geol. Soc.*, vol. lxi, 1905, p. 594.
[3] Reynolds & Gardiner, *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, p. 92.
[4] Cox, *Quart. Journ. Geol. Soc.*, vol. lxxi, 1915, pp. 312–14.
[5] Harker, *Nat. Hist. Igneous Rocks*, 1909, p. 369.
[6] Crook, *Min. Mag.*, vol. xvii, 1914, p. 72.
[7] Cox, *Rep. Brit. Assoc. Birmingham*, 1913, p. 496; and Dewey & Flett, Geol. Mag., 1911, p. 207.

of keratophyres with typical spilites is a proven fact, and that the two are consanguineous can no longer be questioned. If, then, the individuality of the Spilitic Suite be admitted, it becomes necessary to distinguish between Atlantic and Spilitic rocks of like chemical and mineral composition, if such exist. For this reason "soda granite-porphyry" is too wide a term to apply to the intrusive rocks under discussion, as it includes not only these alkaline derivatives of a magma of spilitic affinities, but also similarly constituted members of what the writer may be forgiven for calling the ordinary Alkali Suite—the Atlantic Suite of Harker.

It appears, therefore, that there is no name in current petrographical nomenclature which has a special claim or, indeed, is specially applicable to these rocks, other than the lava name, which has the further justification of usage in this sense on the Continent for a long period of years. Taking this into consideration, together with the practical identity of mineral composition and microstructure of both intrusive and extrusive keratophyric rocks, there seems no reasonable objection to using the one name for both, there being several precedents for this procedure. The only alternative is to coin a new name for the intrusive equivalents, restricting "keratophyre" to lavas. This seems quite unnecessary, and there is much to be said for uniting all these rocks under one name, distinguishing between lavas and intrusions by using the qualifiers "intrusive" and "extrusive", if this should be thought necessary.

V. Further Classification of Keratophyres.

Assuming that "keratophyre" can be so used, it remains to see whether any further classification can be effected. Obviously such further subdivision cannot be made on the basis of the dark mineral content, as in the great majority of cases no original coloured mineral remains. Some of the Tayvallich keratophyres contain small irregular flakes of either brown or green biotite, but it is doubtful how much of this is primary, some part being certainly secondary, derived from the introduction of basic material from the adjacent pillow-lavas.[1] Only rarely have recognizable pseudomorphs been reported from British keratophyres; those from Skomer Island appear to have contained both rhombic pyroxene and olivine, the albite-trachytes of the Benton Volcanic Series,[2] the extrusive keratophyres of the Trefgarn Volcanics,[3] and those of Abercastle all contain pseudomorphs after rhombic pyroxene. The keratophyric "andesite" of the Eastern Mendips is yet another example containing beautiful chloritic pseudomorphs after the same mineral. These are exceptions, however, and most keratophyres contain only scales and fibres of chlorite, even these being far from abundant. There is evidently no basis of subdivision here. The only *qualitative*

[1] "Geology of Knapdale, etc.": *Mem. Geol. Surv.*, 1911, pp. 92–3.
[2] *Geology of the South Wales Coalfield*, part xi, Haverfordwest, p. 6.
[3] Ibid., p. 22.

factor which can be so used is micro-structure, which will be considered later.

The occurrence of free quartz in notable amounts in the most acid keratophyres has created the need for distinguishing "keratophyres" (intermediate) from "quartz-keratophyres" (acid). The only synonym by which the latter name has been seriously challenged is "soda rhyolite". But it should be noted that this is a wider, more embracing term than "quartz-keratophyre", as it covers not only the latter, but also the acid sodic lavas of the Atlantic Suite. The argument formulated against the use of "soda granite-porphyry" is equally applicable to "soda rhyolite" (and "soda trachyte" also). The two primary groups into which the acid lavas should be divided are (*a*) potash rhyolites, and (*b*) soda rhyolites. The latter comprises two sub-groups: (i) soda rhyolites of the Atlantic Suite, and (ii) soda rhyolites of the Spilitic Suite. Sub-group (i) includes comendites and the more acid pantellerites, while (ii) is equivalent to quartz-keratophyres.

It has been suggested by some and believed by many others that the keratophyres are merely the ancient and altered representatives of the comparatively modern and fresh pantellerites and comendites. If such were the case there would be no more justification for the retention of "keratophyre" than there is for the use of "diabase" for altered dolerites, or "propylite" for altered andesite. But such does not appear to be the case. Mineralogically and chemically the two groups are distinct. The relatively low percentage of alumina, high iron oxides and soda have resulted in the formation of sodic amphiboles and pyroxenes in pantellerites, while in keratophyres for the same silica percentage the proportion of alumina is higher and iron oxides much lower, so that non-sodic coloured minerals were formed. These most acid members of the Spilitic Suite are distinct not only mineralogically and chemically, but also genetically, from the acid Atlantic lavas, and their nomenclature should indicate the fact. It is suggested, therefore, that "keratophyre" should be restricted to the intermediate members of the Spilitic Suite, both intrusive and extrusive, the rocks being characterized by a high percentage of sodic felspar, usually an acid plagioclase near albite in composition, accompanied by a small proportion of dark minerals, now represented by chloritic or serpentinous pseudomorphs. Quartz-keratophyres are the corresponding acid rocks, carrying in addition notable amounts of free quartz. Both are apparently free from felspathoid minerals. Any further subdivision can be carried out on the basis of textural differences. There is little doubt that all the textural variations exhibited by the fresh acid and intermediate lavas of other suites will in time be discovered in keratophyric rocks. The following textures have already been noted: cryptocrystalline, microcrystalline, variolitic, felsitic, trachytic, almost pilotaxitic, and orthophyric. There is no need to disguise these differences under a

series of rock names new to the science, but they should be used rather as textural qualifiers in conjunction with "keratophyre" and "quartz-keratophyre". Thus, to speak of an intrusive, orthophyric keratophyre, in the writer's opinion tells the whole story—genetic relations, mineral contents, mode of occurrence, and microstructure all being indicated. The three words could conceivably be replaced by one, but the latter could never be self-explanatory as the former statement is.

VI. Comparison of Keratophyre with Bostonite.

The resemblance of some keratophyres to some bostonites in mineral composition and texture has led to a certain amount of overlapping in the use of the two names, and to uncertainty concerning the restriction of the usage of the terms. In illustration it may be stated that Washington [1] labels the bostonite of Marblehead Neck "keratophyre (bostonite)". The relative scarcity of dark minerals, the predominance of alkali felspar, often strongly sodic, the absence of felspathoids and sodic "pyriboles" are features shared by both rocks. In this country there is general agreement in restricting "bostonite" to intrusive rocks, although this is not the case in the United States, and some doubt exists as to the actual mode of occurrence of the type rock.[2] Recently an attempt has been made to widen the definition so as to include, in addition to hypabyssal bostonites, those lavas possessing the same chemical and mineralogical features. The suggestion was not accepted, however, by the committee who recently reported on the Nomenclature of British Petrography.[3]

Considering, now, recent definitions of bostonite, the latest is that of Holmes, who defines the rock in the *Nomenclature of Petrology* as a leucocratic alkali syenite-aplite with trachytic texture formed almost wholly of alkali felspars. In Hatch's description of the same rocks, the kinds of alkali felspar are enumerated, comprising microcline, anorthoclase, perthite, and albite. The last is included in the latest edition only.[4] In this connexion it may be noted that until recently the felspar of bostonites was regarded as being sodi-potassic. Each of the analyses recorded in Washington's *Chemical Analyses of Igneous Rocks* shows almost equal amounts of soda and potash, the average of six analyses yielding Na_2O 5·13 per cent, and K_2O 5·38 per cent. It may be wondered, therefore, whether the recent addition of albite to the above list may be due to the confusion mentioned above of "keratophyre" with "bostonite". The felspar characteristic of, and commonly found in (intermediate) keratophyres is albite. That characteristic of (intermediate)

[1] Washington, *Chemical Analyses of Igneous Rocks*, p. 146.
[2] Iddings, *Igneous Rocks*, vol. ii, p. 160.
[3] *Report on British Petrographic Nomenclature*, 1921, p. 144 (see "trachyte").
[4] Hatch, *Text Book of Petrology*, part i, Igneous Rocks, 1913, p. 239.

bostonites is soda-orthoclase. With the incoming of lime, as in maenaites, the latter is replaced chiefly by oligoclase.

Although a perfect flow-structure was a striking feature of the original bostonites, it is doubtful whether this name can with advantage be restricted to rocks showing this texture. Rocks undoubtedly exist which chemically, mineralogically, and genetically are like the type bostonites, but which differ from them in texture. Are these to be given new names, or are they not sufficiently described by using "bostonite", with an appropriate textural qualifier? It must be admitted that the presence or absence of flow structure is of no petrogenetic significance, and therefore of no classificatory value. The writer would much prefer to use the name for a rock containing a certain assemblage of minerals, and derived always from the same parent magma. Bostonite is known to be one of the ultimate products of differentiation of a soda-syenitic magma, those derived from nordmarkite carrying free quartz, those derived from laurvikite being free from this mineral. Now a true bostonite can be born of no other parents, neither calc-alkaline nor spilitic. For example, it is a mistaken policy to designate as "bostonite" acid veins in an albite-diabase from East Devonshire.[1] The latter rock is a spilitic rock, probably the intrusive representative of the spilites. The straining of this magma towards the alkali pole would result in the production of a keratophyric not of a bostonitic rock.

The essential difference between keratophyre and bostonite lies not so much in mineral composition and texture, as in *descent*. By taking *descent* duly into account all danger of overlapping disappears, even with rocks which may be so nearly homeomorphic as these two sometimes are.

A Boring at Calcutt, near Cricklade, Wiltshire.

By L. Richardson.

In the early half of 1922 a boring ("jumped") was made by Mr. H. G. Godwin, of Quenington, Fairford, Gloucestershire, for Mr. Oswald Collier, of Calcutt, in search of water. The site of the borehole is at Calcutt—$\frac{1}{4}$ in. above the "C" in Calcutt on 6 in. map, 5 S.W., Wilts.

Calcutt is on the Oxford Clay, $3\frac{1}{2}$ miles south-east of the outcrop of the basement-beds of the formation near The Fosse (by the side of the Ermin Street, about half-way between Cricklade and Cirencester), and $2\frac{1}{4}$ miles north-west of the outcrop of the top-beds of the formation near Broad Blunsdon, where the Oxford Clay is succeeded by the Corallian.

[1] Abstracts from *Proc. Geol. Soc. London*, No. 1,076, 1921, p. ii.

BOREHOLE AT CALCUTT.

		Thickness.	Depth.
Surface-level.—260 ft. above ordnance-datum.		ft. in.	ft. in.
Oxford Clay	1. Clay, with an occasional layer of septaria	193 6	193 6
	2. Rock	0 6	194 0
Kellaways Beds	3. Sand, grey, very fine-grained. (Yielded about 30 gallons of water per hour, but the fine sand hampered the pumps.) .	25 0	219 0
	4. Clay, very hard	13 0	232 0
	5. Sandstone, grey, calcareous, extremely hard	18 0	250 0
	6. Clay, apparently finer textured than 1 and 4	18 0	268 0
Cornbrash	7. Limestone, bluish-grey, shelly, "mixed with clay" (see below): penetrated	5 0	273 0

As the hole was "jumped" it was a difficult matter to obtain proper samples of the rocks passed through, but satisfactory specimens of beds 3, 5, and 7 were brought up. Those of the sandstone, bed 5, were of Kellaways Rock. Those of bed 7 were bluish-grey, shelly (chiefly fragments of oysters) limestone, similar to the well-known Forest Marble limestones. Mr. T. Rylands informed me (*in litt.*, 29th May, 1922) that he understood that this rock was "mixed with clay". This remark, together with the appearance of the limestone, is very suggestive of Forest Marble Series; but if such were the case the Cornbrash would be absent, because bed 5 is definitely Kellaways Rock. But, as the Cornbrash is well developed along its outcrop near The Fosse; as similar difficulty was experienced in identifying it in the cores drawn at the Pumping Station, Lewis Lane, Cirencester; as when unweathered, deep down, it would be of a bluish-grey colour; and, as along its outcrop it is often rubbly and mixed with some marly clay, I am disposed to regard bed 7 as its subterranean continuation.

The water obtained from bed 3 "proved to contain a large amount of salt" (Mr. T. Rylands, *in litt.*, 2nd May, 1922). It is a well-known fact that water from the Oxfordian (Oxford Clay and Kellaways Beds) is usually highly mineralized, and unfortunately it has been established that waters in the Oolites, perfectly fresh when uncovered by the Oxfordian, are as a rule mineralized when tapped beneath such a covering. Thus Mr. G. J. Churchward, the Engineer to the Great Western Railway, informed the late W. W. Fisher that a year or two previous to 1904 he tested by borings the waters beneath the Oxford Clay from Swindon to Kemble (where the clay ends), and found that the chlorine diminished all the way to a point about a mile and a half on the Swindon side of Kemble station.[1]

The Cornbrash did not yield any water worth speaking of, and as that from the sand of the Kellaways Beds was inadequate, salty, and the fine sand would have proved troublesome for the pumps, the borehole was abandoned.

[1] *The Analyst*, vol. xxix, No. 35, February, 1904, p. 37.

Banded Precipitates of Vivianite in a Saskatchewan Fireclay.

By J. Stansfield, M.A., F.G.S.

(By permission of the Director of the Geological Survey of Canada.)

(PLATE XVI.)

WHEN visiting the fireclay quarry of the Dominion Fire Brick and Clay Products Company at Claybank, Sask., during the summer of 1918, the writer noticed an occurrence of banded precipitates in the fireclay of one part of the quarry. Through the kindness and courtesy of Mr. H. G. Love, Managing Director of the Company, a collection of some examples of the occurrence was made and forwarded to the writer for further examination.

The fireclay worked by the Dominion Fire Brick and Clay Products Company is exposed on the slope of the escarpment of the Missouri coteau, which, at Claybank, is facing north, though generally the coteau faces north-east. Usually, the coteau is covered with drift deposits, and Claybank is one of the few points along it at which the Tertiary strata to which the fireclay belongs are exposed. The fireclay has been described in the reports of the Geological Survey of Canada, and also of the Mines Branch, Department of Mines.[1]

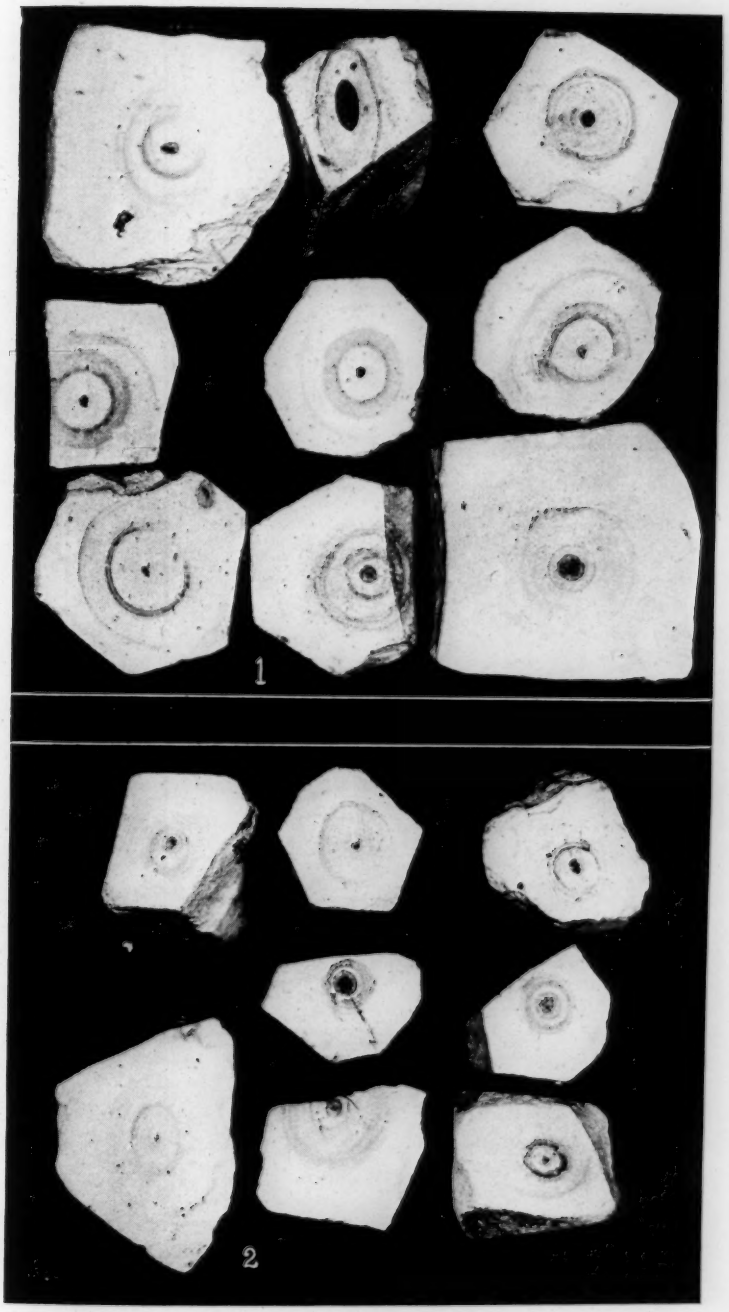
In the quarry the fireclay has a light grey colour. At the northern part of the floor of the quarry, as exposed during the summer of 1918, some bluish-black spots of circular or elliptical outline were noticed, which are the subject of this paper.

The stained parts of the clay are sometimes spherical in outline, sometimes ellipsoidal, and often elongated so as to approach the cylindrical, with rounded ends. The stains vary in diameter from $\frac{1}{6}$ in. to $1\frac{1}{2}$ in., less than $\frac{1}{2}$ in. in diameter being usual. The greatest length of axis noticed in a cylindrical case is one inch, but only part of the whole specimen was available.

The bluish-black stain is deepest in colour at the centre of the sphere, or along the axis of the cylinder. Around the central stain there may be a non-banded stain of less intense colour, or there may be one, two, or three separate concentric stains of similar kind, but not quite so dark in colour as the central stain. In true cross-sections these stains have an approximately circular outline (see Fig. 1 centre), though in some cases the circle may not be complete (see Fig. 1 upper left). Inclined sections of the cylindrical examples show elliptical shapes (Fig. 1, top, middle; Fig. 2, bottom, left and right), and longitudinal sections of the latter show parallel lines on each side of the axis.

The clay between the bands may have the same colour as the normal clay, or it may have a slightly darker colour, owing to the presence of a small amount of the pigmenting material (Fig. 1,

[1] Ries & Keele, *Mem. 24E Geol. Surv. Can.*, 1912, pp. 84-92. Davis, N. B., *Report on the Clay Resources of Southern Saskatchewan*, 1918, pp. 66-71.



Banded Vivianite in Fireclay: Claybank, Sask.

[To face p. 376.

top, middle and right; Fig. 2, top, middle). In some cases one of the bands, or one part of it, may be seen to consist of two or more very closely contiguous bands (see Fig. 1, lower left; Fig. 2, centre, and lower left).

Some examples show bands which are excentric (especially Fig. 2, upper left and bottom, middle).

The bluish-black pigmenting material of these stains loses colour on heating, gives an iron borax head, dissolves readily in hydrochloric or nitric acid, and gives a definite phosphate reaction. It is presumed that it is the earthy amorphous variety of vivianite. Under the microscope it is opaque, though a few flakes can be found which show a pleochroism and birefringence which agree with those of vivianite.

An examination into the possible mode of formation of these stains brings out several points of great interest. It is supposed that the vivianite has been formed by precipitation as a result of reaction of solutions carrying iron and phosphate, the iron solution being dilute and deriving its iron from the general mass of the fireclay, which contains only a trace of iron, and the phosphate solution being more concentrated and derived from some phosphatic body in the clay. The phosphatic body may have been bone, fish scale or coprolite, if of animal origin, or plant root or stem, if of vegetable origin (phosphates being essential constituents of plants). From the information available at present no definite conclusion can be reached with regard to the original character of the central phosphatic bodies.

From their general characters, as described above, there can be little doubt that the stains under discussion have been formed as a result of diffusion of solutions in opposing directions, as the somewhat similar "rhythmic precipitates" are formed in gelatine, agar, etc.[1] In the opinion of the writer the colloidal material of the fireclay itself formed the medium through which the diffusion took place. The vivianite bands are unlike Liesegang rings, which become wider apart away from the centre of diffusion, and they are also unlike the modifications produced by the writer, which are evenly spaced under certain conditions, or becoming closer together away from the centre of diffusion under certain other conditions (op. cit., pp. 19–21 and 24).

Examination of the accompanying photographs will show how the spacing of the bands of vivianite varies and appears to follow no law which has yet been worked out in connexion with banded precipitates. In discussions of banded precipitates which have appeared up to the present time the effect of the medium through which diffusion takes place, upon the reaction, has either been supposed to be very slight, or has been neglected. When dealing with certain reactions in gelatine the effect of the medium appears

[1] *Amer. Jour. Sci.*, Ser. IV, vol. xliii, 1917, pp. 1–26

to be very slight. In the case of the reaction of potassium iodide and lead nitrate in gelatine, the medium appears to have some distinctly disturbing effect upon the reaction (op. cit., p. 25). The precipitates formed in the experiments cited appeared to be continuous, even to microscopical examination. When the plate on which the reaction had been carried out was placed in a bath of sodium hydroxide solution, a set of bands appeared suddenly in the lead iodide precipitate, and they resembled the vivianite bands under discussion in their apparently irregular spacing and also in the presence of precipitate throughout the spaces between the bands, which also occurs in some cases of the vivianite precipitate in fireclay.

It is to be expected that investigation of the effects of the media upon the reactions of solutions diffusing through them will add very considerably to our knowledge of banded precipitates.

Note on the Llwydmor Bâch Granophyre.

By Albert Heard, M.Sc., F.G.S., University College of South Wales and Monmouthshire.

[This paper was submitted to the Editor of the Magazine three weeks before the publication of Mr. N. L. Silvester's paper.[1] I commenced work on the area early in the summer of last year, and apparently Mr. Silvester began at about the same time, but as he has secured priority of publication I have decided to postpone further work and publication on the district.—A. H.]

[Mr. Silvester's paper was in the Editor's hands for some months before publication. It was sent to the printers before the existence of Mr. Heard's MS. was known to the Editor.]

I. Introduction.

THE rock which is described in this communication, occurs along the western flank of Llwydmor Bâch, about 6 miles east-south-east of Bangor, and about 8 miles south-west of Conway. On the 1 in. map of the Geological Survey,[2] this rock, together with entirely different types on its eastern margin, are all marked as intrusive felspathic rocks. On the $\frac{1}{4}$ in. map,[3] it is described as granite, and its eastern boundary is mapped.

The outcrop of the rock is in the form of an elongated lenticular mass, about 3 miles long by $\frac{1}{2}$ mile wide, with the long axis having a direction north-north-east—south-south-west (approximately).

In the field the typical rock weathers generally into relatively thin flaggy slabs, which occupy the lower crests of Llwydmor Bâch, and form small screes on the slopes.

Two distinct rock types are present; the interior of the laccolith consists of a granophyre, whilst near the margin practically all

[1] Geol. Mag., Vol. LIX, 1922, p. 134.
[2] Sheet 78 S.E. Geol. Surv. of England and Wales, Old Series, 1852.
[3] Sheets 9 and 10, $\frac{1}{4}$ in. Geol. Surv. of England and Wales.

trace of granophyric intergrowth is lost, and the rock becomes normally granitoid.

II. The Granophyre.

Fairly fresh specimens are easily obtained. Hand specimens from the centre of the laccolith present a patchy appearance, with dark aggregates in a pink matrix. The dark coloured basic patches, which are almost invariably rounded, appear to constitute about a quarter of the rock, and vary considerably in size; ovoid masses, more than 2 inches across, have been observed. In the leucocratic portion, idiomorphic felspars, surrounded by pink micropegmatite, are abundant.

Under the microscope the rock is seen to consist essentially of various felspars, quartz, pyroxene, secondary amphibole, and chlorite. The dominant felspar is an idiomorphic plagioclase, often badly weathered, but containing many fairly fresh portions, which, by their well-developed albite twinning, enable the felspars to be determined as oligoclase. The refractive indices of these felspars show that in many cases albite-oligoclase is present in the outer parts of the crystals. Laths of secondary mica occupy a large portion of the weathered phenocrysts: these sericite laths are arranged in lines parallel to the felspar cleavage.

The boundaries of these idiomorphic felspars are well marked, often by a "dirt" band, and practically all are surrounded by a growth of a microperthitic felspar, which is presumably near to anorthoclase in composition.

The anorthoclase zone is itself surrounded by micropegmatite. The graphic intergrowth shows the usual variations in arrangement, due to differences in grain. It is frequently in optical continuity with the outer, or anorthoclase, zone of the larger felspars.

Quartz is fairly abundant, occurring both interstitially and in granophyric intergrowth with the felspars. It is frequently present in the form of a mosaic, along with microperthite and an untwinned water-clear felspar, which has a refractive index less than quartz. The mosaic appears to have some relation to the clots of basic material, since it generally occurs, partially but not completely, surrounding the patches of ferro-magnesian minerals. This type of quartz contains characteristic lines of gas and solid inclusions, including needles of amphibole and small albite crystals, and apparently is not of secondary origin. Most of the inclusions are confined to the inner areas of each mosaic. The micropegmatitic quartz exhibits every gradation from that of a relatively large crystal of quartz containing thin bands of felspar, to the finest intergrowth. Micropegmatite is not limited to areas surrounding the felspar phenocrysts, but occurs also as a interstitial constituent, in the body of the rock.

The majority of the ferro-magnesian minerals are segregated throughout the rock in groups, which in certain respects may be

compared with the glomero-porphyritic aggregates in a lava. A colourless non-pleochroic augite is abundant, and is frequently represented by secondary products; the freshest augite occurs near the centre of the ferro-magnesian aggregates. The commonest alteration is to a fibrous uralitic amphibole with pleochroism, bluish parallel to *c*, strong green parallel to *b*, pale yellowish-green parallel to *a*. The fibres of this uralite frequently penetrate the surrounding crystals. In many cases a core of augite is present in crystals of amphibole. Hydrated iron oxide is present in the cracks in the augite, and a slightly pleochroic chlorite with an extremely low birefringence is a common alteration product of the pyroxene. Occasionally a sahlitic striation is observed in the centre of the augite crystals.

An interesting feature is the presence of elongated idiomorphic prisms, consisting mainly of uralite and bastite; these are often intergrown with the augite, and apparently are pseudomorphs after rhombic pyroxenes, although no fresh rhombic pyroxenes have been observed.

Apatite, in elongated prisms, is unusually abundant in the basic patches. Some of the prisms show long central cavities. Magnetite and titaniferous magnetite are abundant in the "clots", though the granules are seldom found outside the basic patches. Many of these iron ores are enveloped by a pellicle of chlorite. Epidote occurs, generally in association with the ferro-magnesian minerals. Biotite and hornblende of a primary nature have not been observed.

III. The Granite.

Near the edge of the laccolith, the micropegmatite disappears almost entirely, and the rock becomes a normal granitic rock. In hand specimens, it appears greyish, with the ferro-magnesian constituents more evenly distributed than in the granophyre described above, although small basic patches do occur. The pinkish colour of the micropegmatite is, of course, absent from the hand specimen of this marginal type. Fresh specimens are rather difficult to obtain, though under the microscope most of the constituents may easily be identified.

A characteristic feature of this marginal rock is the presence of relatively large amounts of interstitial quartz, undoubtedly primary, containing numerous inclusions of earlier formed minerals, amongst which needles of amphibole are particularly abundant.

The felspars are mainly of idiomorphic habit, similar to those described as occurring in the granophyric type; the polysynthetic twinning may be observed. The outer zones are very much weathered, but probably consist of the microperthite described above. Granophyric structure is almost entirely absent from this marginal type of the laccolith.

In contrast to the granophyric type, augite is wanting, and the crude glomero-porphyritic structure of the ferro-magnesian minerals

has disappeared; the few ferro-magnesian constituents are more evenly distributed, and have a tendency to form irregular broken bands. They consist mainly of uralite and chlorite, apparently after a rhombic pyroxene. The outer edges of many of these pseudomorphs consist of a strongly pleochroic dark mica. The absence of primary mica and amphibole is conspicuous. The small basic patches consist of badly weathered felspars, quartz, fibrous amphibole and chlorite, much finer in grain than the surrounding groundmass. Surrounding these basic patches is an envelope of interstitial quartz. This envelope is more pronounced than that which surrounds the basic aggregates in the granophyric rock.

IV. Conclusions.

Both the granitic and the granophyric types described above apparently belong to the same rock mass, as an examination of the laccolith in the field affords no evidence which suggests that it was not formed from a single intrusion. R. H. Rastall [1] describes and discusses in detail the occurrence of a micropegmatite within an intrusive mass, and an outward transition to a normal granitic rock; and as far as the leucocratic constituents are concerned, the Llwydmor Bâch Granophyre forms a parallel to the Buttermere and Ennerdale Granophyre.

Chemical analyses are not yet available, but a microscopic examination reveals the fact that the micropegmatite is more basic than the granite. This higher basicity of the interior of the laccolith is due to the presence of the "clots" of pyroxenes and amphiboles. These basic patches are presumably cognate xenoliths which are relatively undisturbed in the well-developed micropegmatite. There is a tendency for these basic aggregates to be distorted with a diminution of the monoclinic pyroxene as the rock approaches the margins of the laccolith.

The Llwydmor Bâch Granophyre is apparently an intratelluric hybrid, an acid rock, which had become impregnated with a solidified basic magma, or had the dregs of a partially solidified local magma reservoir injected with the still liquid acid portion.

A New Brachiopod (*Leptestia*) from the Kuckers Stage in Estonia.

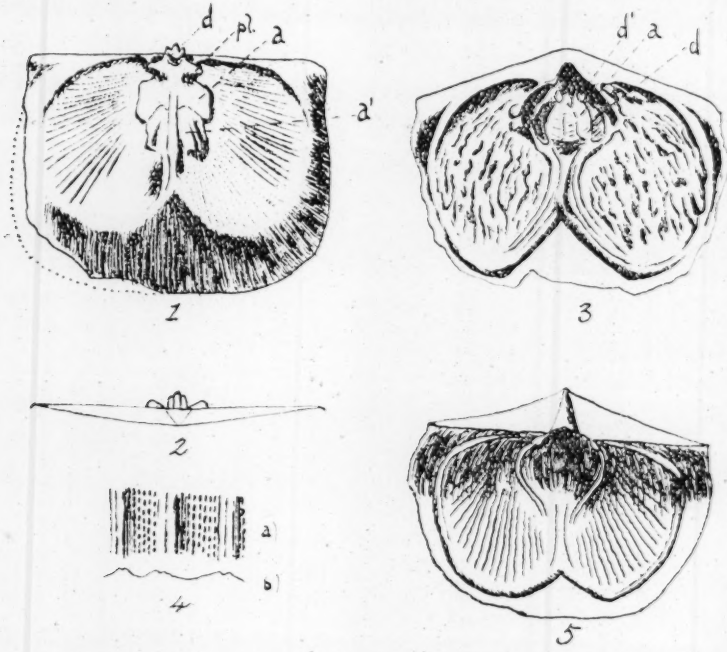
By Hendrik Bekker, Ph.D. (London).

Among the Brachiopoda described in my recent memoir on the Kuckers stage of north-east Estonia, there was an undetermined member of the *Strophomenacea*, of which the interior of the dorsal valve was unknown. I have since found a dorsal valve with its exterior (concave) outwards, embedded in kuckersite. By filling the concavity with plaster of Paris the shell could be easily removed

[1] R. H. Rastall, *Quart. Journ. Geol. Soc.*, vol. lxii, 1906, p. 253.

from the kuckersite. A complete description can now, therefore, be given. Since my return to Estonia I have found additional examples of the same species[1] and of another species of the same genus among the collections of the Tartu (Dorpat) Museum, which were removed into Russia during the war, and have now been returned.

I am indebted to Dr. A. M. Davies for reading the manuscript and proofs. I wish to express my thanks to the officers of the British Museum for the use of the Gray collection from the Girvan district.



FIGS. 1–4.—*Leptestia musculosa*, sp. nov. 1. Dorsal valve, × 2. *a*, posterior adductors; *a'*, anterior adductors; *d*, diductor marks; *pl*, hinge-plates. 2. Area with cardinal process, × 2. 3. Ventral valve, × 2. *a*, adductors; *d*, diductor marks; *d'*, accessory diductors. 4. Shell surface, anterior region, × 20. *a*, surface; *b*, section. FIG. 5.—*Leptestia* sp., ventral valve, × 2.

LEPTESTIA,[2] gen. nov.

Diagnosis.—Valves dorso-ventrally concavo-convex, rounded-quadrangular in outline, widest anteriorly. As distinctive features may be named:—

(1) The elliptical visceral fields of both valves internally.

[1] Labelled in the collections *Leptaena transversalis* Wahlenb.

[2] The name is composed of *Lept-* from leptós; and *estia* from Eesti (Estonia).

(2) The muscular platform of the dorsal valve, with an elevated septum and a trifid cardinal process.

(3) The more or less sub-parallel shell-callosities of the visceral fields in the ventral valve, surrounded by shell-thickenings, which proceed as dividing branches from the septal process.

(4) The strong dental lamellæ of the ventral valve, with attached curved ridges, enclosing the muscle-area and the septal process.

(5) The surface structure.

Genotype: *Leptestia musculosa*, sp. nov.

LEPTESTIA MUSCULOSA, sp. nov. (Text-fig. 1–4.)

Undetermined Brachiopod of the Strophomenacea, 1921, H. Bekker, "The Kuckers Stage of the Ordovician Rocks of North-East Estonia," *Acta et Commendationes Universitatis Dorpatensis*, A ii, 1, p. 77, pl. i, figs. 13–14; pl. iv, fig. 13.

Diagnosis.—Outlines of valves, which are normally concavo-convex, rounded-quadrangular, widest anteriorly. Area nearly straight, that of the ventral valve more elevated and the umbo of this valve slightly produced above the area. Visceral fields broad, clearly marked, elliptical. The muscular region of the ventral valve in the umbonal cavity, surrounded by elevated dental lamellæ. In the dorsal valve a platform for the adductors, the cardinal process trifid.

Material.—Author's collection in Tartu, Estonia: two ventral valves, one dorsal valve. Three ventral valves and three complete specimens in the Geological Museum, University of Tartu.

Locality and Horizon.— Kohtla-Järve, Kuckersite quarry. Kuckers stage, C 2, Ordovician. Tallinn (Estonia); Pavlovsk (Russia), C 16.

	Dors. V.	Ventr. V.
Measurements.—Width at hinge-line .	19·5 mm.	23·5 mm.
Greatest width . .	20	23·5
Length . . .	16	20·5

Description: Ventral Valve.—The area is slightly triangular, delthyrium moderately broad. Shape of the teeth not seen, as the valve unfortunately is slightly weathered, but they are supported by rather strong dental lamellæ (Fig. 3); two curved ridges touch the dental lamellæ anteriorly, enclosing the muscular area and a slightly elevated septal process, which proceeds anteriorly from the muscular area, dividing nearly in the middle of the length of the shell, and encircling two large elliptical visceral fields; these show shell-callosities, a number of more or less parallel wrinkles (? ovarial markings). The muscular area shows marks of the diductors as well as accessory diductors; the diductors enclose adductor marks.

Dorsal Valve.—Has an almost straight area, slightly inclined towards anterior end (Fig. 2). The trifid cardinal process is elevated above the hinge-line, and shows anteriorly two well-developed grooves; on its back it shows mark of the diductor scar (Fig. 1).

Well-developed hinge-plates enclose deep sockets for the teeth of the ventral valve, and these plates proceed anteriorly, forming elevated platforms for the adductors, well-defined for the anterior pairs, the first slightly folded. The muscular area is divided by an elevated septum which is highest in the middle of the length of the shell and ends at the beginning of the elliptical visceral areas, which are slightly concave, and show fine striations, strongest in their middle. From the visceral fields the valve bends more or less abruptly towards the anterior and lateral margins.

External Ornament.—The stronger striæ or ribs appear to be hollow and when slightly weathered on the surface give the appearance of double striæ. Between any two of these there are four to six rows of longitudinal elongated pits or punctures. Anteriorly the shells have several irregular longitudinal undulations.

LEPTESTIA sp.

Material.—One ventral valve (interior), Geol. Mus. Univ. Tartu.

Locality and Horizon.—Rakvere (Vesenberg), Rakvere stage, E.

Measurements.—Greatest width . . 20 mm.
Width at hinge-line . 18 mm.
Length . . . 15 mm.

Description.—The ventral valve is less convex than that of *L. musculosa*. The area moderately high, slightly concave ; the narrow delthyrium covered by a deltidial plate. Teeth rather strong, supported by lamellæ, which are less strong than those of *L. musculosa*. The septal process is only slightly marked. The shape of the clearly bounded visceral fields with parallel ribs is rounded-angular, and recalls the shape of those fields in *Davidsonia verneuiliana*. Exteriorly the ribbing is essentially the same as that of *L. musculosa*, but there are only two to four rows of pits between any two of the stronger ribs.

Generic relations.—It is of interest to note the relation of *Leptestia* in some characters to different members of the Strophomenidæ. *Rafinesquina alternata* [1] (Conrad) shows a very similar platform of the adductor muscles, but the new form differs from it considerably in its cardinal process, visceral fields, and ventral valves. The visceral field of *Leptella* [2] shows resemblance to that of *L. musculosa*, but it differs considerably near the hinge-line. Undoubtedly related to *Leptestia* is *Plectambonites leptelloides* Bekker,[3] with a very similar visceral field of the dorsal valve, only the latter has no highly developed marks of the adductors and its cardinal process shows

[1] Hall & Clarke, *Palæontology of New York*, vol. viii, 1892, pl. viii, fig. 9.

[2] Hall & Clarke, op. cit., p. 293, pl. xv A, fig. 15.

[3] I am indebted to Professor O. T. Jones for calling my attention to the fact that *P. schmidti* var. *leptelloides* Bekker, described in my memoir (H. Bekker, "The Kuckers Stage of the Ordovician Rocks of N.E. Estonia": *Acta et Comm. Univ. Dorpatensis*, A ii, 1, p. 68, pl. iii, fig. 16 ; pl. iv, fig. 12 ; pl. v, figs. 9–13), is a distinct species and I replace the latter name by that of *Plectambonites leptelloides* Bekker.

anteriorly only two very faint grooves, which by stronger development produced the trilobation of the cardinal process of *Leptestia*; the differences of the ventral valves are still more pronounced, as: (1) the shell-callosities of *Leptestia* in the visceral fields; (2) its shell thickenings or ridges around the visceral fields; (3) its surface structure.

Plectambonites llandeiloensis (Davidson)[1] is related to *Leptestia*, as well as to *P. leptelloides*, especially by its slightly similar visceral fields of the dorsal valve. *Davidsonia verneuiliana* Bouchard [2] has muscular impressions in the umbonal cavity with almost the same arrangement. The conical shell callosities and spiral markings of *Davidsonia* are absent in *Leptestia*. *Davidsonia* does not possess dental lamellæ and a septal process. The dorsal valves differ more considerably; the exterior adductors of *Leptestia* enclose only a portion of the interiors, while the interior pair is enclosed by the exterior in *Davidsonia*. The cardinal process differs also. It might be suggested that *Leptestia* is an ancestral form of the middle Devonian *Davidsonia*, and the differences are naturally due to the mode of life (*Leptestia* is a free form, while *Davidsonia* is fixed by its ventral valve), as well as to the great lapse of time.

An Aeolian Pleistocene Deposit at Clevedon.

By Edward Greenly, D.Sc., F.G.S.

[This paper was read before the Geological Society of London, and discussed, on 1st December, 1920. Subsequently, however, I asked and obtained leave from the Council to withdraw it from publication, in order to relieve the pressure on the *Quarterly Journal*, as has been announced in *Proc. Geol. Soc.*, 1920–1, p. iv, footnote.]

Introductory.
General Aspect.
Petrological Characters.
Structures.
Physical Features of the District.
Distribution and Relations of the Deposits.
Palæontology.
Local Detail.
The Age of the Deposits.
The Origin of the Deposits.
The Loess—a Comparison.
The Contemporary Levels.
Sources of the Materials.
Recapitulation.

Introductory.

THE deposits which are the subject of this paper have already attracted some attention, because of their connexion with the contents of a small, though highly fossiliferous bone-cave at a place

[1] F. R. C. Reed, "Ord. and Sil. Brach. Girvan district": *Trans. Roy. Soc. Edinburgh*, vol. li, 1917, pt. iv, p. 376, pl. xiii, figs. 32–4; pl. xiv, fig. 1.

[2] T. Davidson, *Brit. Dev. Brachiopoda*, 1865, p. 74, pl. xi, figs. 13–16; pl. xv, fig. 18. Hall, J., & Clarke, J. M., *Pal. New York*, vol. viii, p. 301, pl. xvA, figs. 31–3.

called Holly Lane (Figs. 1, 2), discovered by Mr. G. E. Male, of Clevedon, towards the close of the year 1905. Mr. Male worked at it for many weeks, and with his brother, Dr. H. C. Male, of Croydon, collected hundreds of bones, though unfortunately considerable numbers had been already thrown away. In the following year Professor Sidney Reynolds also began to collect, and obtained about 500 more. Probably not less than 2,000 have been preserved. They are now in the museums at Jermyn Street (London), Bristol, and Taunton, and in Dr. Male's collection. The vertebrates were named by Mr. E. T. Newton, Professor Reynolds, and Mr. Martin Hinton (with notes by Mr. S. G. Shattock, of the Royal College of Surgeons, and by Professor Sir W. Boyd Dawkins), and the gasteropods by Mr. E. T. Newton, the shells having lately been re-examined and the list revised by Mr. A. S. Kennard.

FIG. 1.—Contoured map of Clevedon. Scale 1·12 inch = 1 mile. HLQ = Holly Lane Quarry. ECG = East Clevedon Gap. DH = Dial Hill. Cas = Walton Castle. CQ = Conygar Quarry. —·— = Alluvium. Heights in feet.

In the present paper we are concerned with the cave only in so far as its contents form a part of the accumulations which are found outside, and which buried it altogether. My own acquaintance with the Holly Lane section began in the late autumn of 1916, when I was taken to see it by Mr. G. E. Male, and we discussed the curious questions presented by it. To account for the phenomena by the action of water seemed to me impossible. It occurred to me, however, that the deposits had certain characters which recalled the descriptions which have been given of the Loess by Richthofen and others, and I suggested to him that a solution of the problem might perhaps be found in æolian action. During the succeeding three years I made further investigations, which brought out more æolian and loess-like features than might have been expected.

General Aspect.

The deposits consist of sandy breccia, loamy sand with stones, loamy sand, and sandy loam, and attain a visible depth of 60 feet, the base, moreover, not being reached at that spot. But they are by no means confined to the Holly Lane section, though that is still the best exposure. They have now been traced across the whole width of the valley (known as the Vale of Gordano), and also for 2 miles westward. Though sometimes very thin and sometimes absent altogether, they seem to be scattered over 2 square miles of country. Where thickest they are banked up against the flanks of the hills, a feature which is extremely pronounced at Holly Lane, as may be seen in Fig. 3.

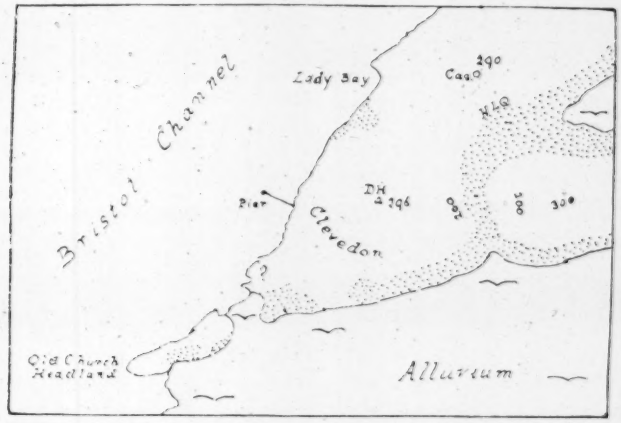


Fig. 2.—Sketch-map of the Pleistocene deposits shown by the stipple. Scale: 1·13 inch = 1 mile. HLQ = Holly Lane Quarry, but letters a trifle to N. of exact spot. DH = Dial Hill. Cas = Walton Castle. For other localities see Fig. 1.

Petrological Characters.

The Breccias are crowded aggregates of angular fragments, usually 3–6 inches, but sometimes a foot or more in diameter, while blocks 5 feet in length are occasionally found. Their angularity is very marked, and rudely tetrahedral forms are very common. The tendency to this form is locally accentuated at Holly Lane by a particular system of jointing in the parent rock (the Caninia oolite); but the triangular faces cannot fail to recall the much-discussed "Dreikanter" of modern deserts. Equally pronounced is their local origin. The breccias are not known to extend more than 60 yards from the hillside crags. At Holly Lane every block examined is from the Caninia oolite of the Carboniferous Limestone[1]; while at East Clevedon Gap nothing but limestones of the Z zone (with one or two blocks of the adjacent Coal Measures), and at

[1] With one solitary but interesting exception, considered on p. 372.

Conygar nothing but the Coal Measure sandstone, have been observed. In every case the blocks are derived exclusively from the formation against whose crags they rest. The breccias have, in fact, so far, the characters of a talus or scree.

They differ, however, from a pure talus in that the blocks are embedded in a matrix of ruddy brown, loamy sand, sufficiently compacted to leave a good hollow cast when they are taken out, and occasionally even cemented by secondary calcite into a tolerably hard rock. Now, this sand is *not* of local origin. It consists for the most part of quartz, but is decidedly poor in white mica. When washed it always yields a tail of heavy minerals (which are enumerated below) and sometimes a front of light ones. The light front consists of thin flakes of land-shells and black carbonaceous débris. The matrix of the Conygar breccias, however, in spite of the fact that the Coal Measure sandstone upon which they rest is rich both in white mica and in coaly débris, contains no carbonaceous matter, and no more white mica than we find at Holly Lane, where the breccia rests against the Caninia oolite. The heavy minerals are the same at Holly Lane as at Conygar, and could not possibly have been derived from the Caninia oolite. Thus it is clear that the breccias are local screes, with a matrix of sand which is of alien origin.

The Stony Sands.—By simple waning of the blocks the breccias graduate into stony sands, the blocks being still angular but of smaller size. In the simpler sands they nearly disappear, but no sand is completely free from blocks. Close to any crag they are as local as in the breccias, but in the broad valley bottoms blocks from the opposite slopes begin to appear, and in places equidistant from crags of different rocks, they are derived in approximately equal numbers from the two sources.

The Loamy Sands.—The composition of all the sands is essentially the same, save that the light shell and carbonaceous débris may be absent, being much greater at Holly Lane than anywhere else. Some flocculent clayey matter is always present. There is the usual overwhelming quantity of quartz and the same poverty in white mica. Nor is there much felspar. Some fragments of a very fine siliceous mosaic, often containing black dust (apparently carbon), may be regarded with confidence as Carboniferous chert. The heavy residues are mainly composed of zircon, tourmaline, garnet, magnetite, and rutile. Staurolite is not rare, and there are small quantities of andalusite, biotite, green hornblende, epidote, and ilmenite, with (I think) a very little monazite.

Some of the quartz is clear, but much of it is dusky with inclusions, and inclusions are abundant also in the garnets and in some of the tourmalines and zircons. The larger grains of quartz are well rounded, with dull, dry-rubbed surfaces, but nearly all the smaller grains are angular. A few, however, show facets of secondary outgrowth, as if derived from Triassic sandstones. The zircons, tourmalines,

magnetites, and many of the garnets are idiomorphic. Most of the rutile is hypidiomorphic, and geniculate or kite-shaped twins are rare.

Contribution by Mr. V. A. Eyles, B.Sc.—Unfortunately, the analyser of my microscope was at that time suffering from a shock received on the railway, besides which I was then obliged to obtain the heavy residues by mere washing with water. These disadvantages, however, have since been made up, for Mr. Eyles, not long before leaving the University of Bristol for the Geological Survey of Scotland, made an examination of the sands with proper appliances, and has kindly communicated his results.

He identified all the above-named minerals, except ilmenite, epidote, hornblende, and monazite. His confirmation of the presence of andalusite (whereof, with my crippled microscope, I had been doubtful) is very important. He found, in addition, kyanite, magnetite, hæmatite, orthoclase, and a little triclinic felspar, some of which is microcline, some apparently albite, some apparently more basic. Dr. H. H. Thomas also identified in his slides a little anatase and brookite. The ruddy colouring matter he regards as limonite, and found also a little cementing calcite.

Most of the tourmaline is greenish-brown, but a little is blue, while a pink variety seems to be present. He notes that there are two varieties of rose-coloured garnet, one worn and of moderate size, the other small and idiomorphic.

He also made (from one sample) the following quantitative estimation of the proportions of the constituent minerals:—

In-sol. in HCl.	Heavy Minerals, Sp.G. > 2·8	0·64
	Minerals, Sp.G. < 2·8	80·26
	Fine Mud	3·00
Sol. in HCl.	Calcite (chiefly)	8·50
	Oxide of Iron (coating grains) and other undetermined soluble matter	7·60
		100·00

Percentage of Heavy Minerals in the grains freed from calcite and iron oxide . . . . . 0·79

The minerals present, besides quartz, calcite, and limonite, are therefore—

Plentiful.	Zircon, Tourmaline, Garnet, Magnetite, Rutile.
Moderate Quantity.	Staurolite, Orthoclase.
Small Quantity.	Andalusite, Biotite, White Mica, Hornblende, Epidote, Kyanite, Hæmatite, Ilmenite.
Very Rare.	Anatase, Brookite, Monazite (?), Albite (?), Basic Felspar (?), Microcline.

The Loams, which are but feebly plastic, are mainly composed of minute angular quartz and a flocculent matter which appears to be limonite. They are calcareous, effervescing slightly with hydrochloric acid, and shell-flakes are common. The loamy component of the sands appears to be of the same general character.

Structures.

Bands of breccia, sand, and loam alternate with each other, especially at Holly Lane (Fig. 3), and lenticular, impersistent beds of sand or loam, about a foot in thickness, are occasionally disclosed within the breccias. But within each band stratification is absent or very feebly developed. Sometimes, in favourable states of weather, very faint signs of it may be detected in the loams. In the sands, bedding may be seen here and there for a foot or two, but it soon dies out. The breccias are tumultuous, the major axes of their great 5 ft. blocks even being often vertical; while the isolated blocks in the stony sands are at all kinds of angles. The purer sands, where furthest from the hills, are quite unstratified. One or two settlement-faults, with displacements of a few inches, have been revealed in the course of the quarrying.

But the most curious character of the fine deposits is the development of a vertical system of divisional planes. It is most pronounced in the loams, and is present even in the impersistent lenticles. The structure cannot be termed a jointing; it is too close; and is better described as a sort of cleavage. For it is so well developed that laminæ no thicker than $\frac{1}{8}$ in. can be flaked off with the hand, and still thinner ones with a knife. No steady strike is perceptible, and, indeed, it shows a tendency to curve with the curvature of the temporary cliffs, as if potential on all vertical planes within the mass, and developed by the weather, particularly frosty weather. The scanty micas are quite insufficient to account for this remarkable cleavage, but we may ascribe it with confidence to the thin shell-flakes, for they stand at all angles, and where they are most abundant it is most pronounced.

The loams are sometimes traversed by minute capillary tubes, often containing black specks and streaks of carbonaceous matter, evidently the remains of vegetation, particularly rootlets. Mr. G. E. Male states that calcareous concretions, with diameters ranging from $\frac{1}{4}$ to $\frac{3}{4}$ in., were not uncommon in the matrix of the ossiferous breccia, and small aggregations of calcite are still frequently to be found in the loams.

Physical Features of the District.

Clevedon is situated at the convergence of two ridges (Fig. 1), each about 270 feet in height, one running westward from Bristol, the other south-westward from Portishead. Both are mainly composed of Carboniferous Limestone, dipping rather steeply in southerly directions; but Old Red Sandstone dips under that of the Portishead ridge, while Coal Measure ("Pennant") Sandstone is brought by a powerful rupture against the north side of that of the Bristol ridge. Outliers of Triassic (Dolomitic) conglomerate cling to the Palæozoic rocks, and the lowlands are underlain by Keuper marl and sandstone, which, however, are seldom visible. The Portishead ridge is washed by the Bristol Channel, but the southern

side of the Bristol ridge looks down upon that great tract of alluvial fen-land which, with a level of about 20 feet O.D., sweeps without interruption to the foot-hills of the Mendips, and through their gaps to Bridgwater and Glastonbury, no less than 24 miles away.

The two ridges enclose a secluded hollow, 5 miles long, already alluded to as the Vale of Gordano, whose romantically wooded sides break here and there into crag. Save for half-a-mile at its south-western end, it is floored by a tongue of the Severn-side alluvium, whose surface is also at the 20 ft. level. But the upper end of this Gordano Valley is altogether anomalous. The Bristol-to-Clevedon ridge is abruptly breached by a huge craggy gap, which we may call "East Clevedon Gap" (Fig. 1), whose visible floor is at hardly more than 5 or 10 feet above the level of the great alluvia, while its rock-floor, buried under the superficial deposits which are our present subject, may be at or even below sea-level. Thus the Vale of Gordano, just where a cirque of heights appears about to close it in, is suddenly laid almost as open to the south-west as it is to the north-east.

Distribution and Relations of the Deposits.

The distribution and behaviour of these deposits is everywhere conditioned strictly by the physiography (Figs. 1, 2). They cling to the southern flanks of both ridges, climbing up to 120 feet above the sea. But in the Vale of Gordano and in East Clevedon Gap they extend completely across the hollows, and climb up the opposite sides as well. Against the crags they are (Fig. 3) banked up thickly—more thickly on southward-facing than on northward-facing crags. They are interrupted at gaps in the ridges. The little cave (Fig. 3) was filled with breccia to within 18 inches of the roof, the breccia resting on some 8–10 inches of dull red stony loam or cave-earth, which lay upon the rocky floor. The breccias and stony sands are confined to the steep flanks of the hills; but the sands and loams are not in converse manner confined to the valley-floors, for they rise up on to the hill-sides, interdigitating with the breccias. At 50 or 60 yards from the crags the bands begin to rise at angles of about 15°, the angle increasing till at the crag-side it is as high as 32° (Fig. 3). The surface in such places is also steep, though not quite so steep owing to the upward thinning of the bands, and the slope falls off rapidly. Its profile across the Vale of Gordano is shown in Fig. 4, and is a highly characteristic curve. On the gentler slopes and the valley-floors their base has not been seen, so that the true thickness is unknown. The lowest level to which they have been traced with certainty is about 30 feet O.D., but there is little doubt that they pass under the great alluvia.

Palæontology.

Determinable fossils have been obtained only at Holly Lane and Highdale Road. The vertebrate forms (see Reynolds, *op. cit.*)

are horse, bear, wolf, fox, Arctic fox (?), rabbit (?), four species of vole, Norway lemming (?), with twenty-four species of birds (including eagle, buzzard, heron, gull, and cormorant). Four fish vertebræ were also found. Mr. Newton's reserve as to the Norway lemming is on account of the lack of jaws and teeth, but he finds that "a goodly number" of limb-bones agree with those of that species. Of the larger vertebrates, the most numerous are horse, bear, and wolf, but more abundant than either are the voles. None of the birds are individually numerous. A curious and interesting circumstance is that the bears were frequently afflicted with osteo-arthritis.

The molluscan forms are—

Hygromia hispida (Linn.).
Helicella virgata (Da Costa).
Helix aspersa Müll.
Pupilla muscorum (Linn.).
Succinea putris (Linn.).

Of these the most abundant forms are *Hygromia hispida* (very plentiful) and *Pupilla muscorum*, which are so characteristic of all late Pleistocene deposits. *Helix aspersa* is known from the Pleistocene of Chudleigh, South Devon, and *Helicella virgata* from the Pleistocene of Santon, North Devon, and Chudleigh, South Devon. All are from Holly Lane except *H. aspersa*, which was only found at Highdale Road, where I think it was *in situ*. A single specimen of *Litorina obtusata* (named by Mr. Newton) is also reported from a former collection. There are no determinable plant-remains.

Reviewing the character of the fauna, we see that the presence of the few sea-birds is easily understood at a position so near to the sea; while the four fish-bones and the doubtful *Litorina* could easily have been brought by the large carnivorous birds. All the rest are land-forms, and it is evident that the fauna, both molluscan and vertebrate, is thoroughly terrestrial.

With regard to mode of occurrence, the mollusca have been found in the loamy sand outside the cave. The greater number of the vertebrates were obtained inside the cave, but they were also plentiful outside, though *always immediately against the crag*, the vole-jaws often in small crannies thereof. Close to the cave's mouth one vole-jaw was found by Mr. Male within the neural canal of a horse's vertebra. With one or two exceptions the bones were all detached and jumbled up tumultuously together, much as are the blocks in the breccias in which they were contained.

No certain signs of the presence of man have been detected, though carefully sought for during the excavations; but some bones are doubtfully regarded as human by Professor Boyd Dawkins. In 1917, however, I obtained at Holly Lane a slab of Coal Measure sandstone an inch thick and weighing 1 lb. 14 oz. It was undoubtedly embedded in the upper band of breccia, for it left a clean smooth

cast when taken out. It was, indeed, the only alien block found in the deposits anywhere, and is the solitary exception to the Holly Lane oolite blocks mentioned above, from which it also differs in being sub-angular. On that side of the valley (Fig. 2), at the 55–60 ft. level, it could not possibly have been carried from Conygar by the agent which brought about the accumulation of the breccia. We may also reject the possibility of its having fallen from some patch of Trias conglomerate concealed among the woods, for no Triassic blocks have been found, and the Triassic outlier at Walton Castle has yielded no fragments of Coal Measure sandstone. It is, in short, almost impossible to imagine how it could have been brought by any "natural" agencies. Further, its corners show some signs of battering, as if used as a hammer, for which its size and shape would be well adapted. Provisionally, therefore, human agency may be suggested as the most likely explanation of its presence.

Local Detail.

This may be difficult to realize from perusal alone. But, as several of the exposures have disappeared altogether, as all of them are liable to rapid change, and as such change now tends not to improvement but to deterioration, the evidence ought to be placed on record. The descriptions will also be a guide to those who may visit the ground.

Holly Lane (Figs. 1, 2, 3).—As this is by far the best section, its leading features have already been described by implication. Its western cliff is the only place where more than two members are to be seen together. There are five bands. The lowest is a sandy breccia with blocks about three inches in diameter. This passes rapidly up into a very coarse breccia with blocks as much as 5 feet long. Then follows, rather abruptly, a sandy loam (the best to be seen anywhere) with capillary tubes and a few small stones. It graduates upward (though so rapidly that the junction is quite distinct in good states of weathering) into loamy sand with about one stone to a square foot of section. The latter is full of little flakes of thin land-shells (which stand at all angles), and well-preserved specimens, especially of *Helix hispida* and *Pupilla muscorum*, have been obtainable at any time during the last three years (1916–20). They are not equally distributed. Most of them occur along a sort of horizon rather below the middle of the band, and in that, too, are apt to occur in little groups or crowds. Both bands display the vertical cleavage well, especially after frost. Upon the sand rests an upper sandy breccia, with blocks usually about 3 inches, but occasionally 2 feet, in diameter. All the bands thin uphill. The most striking feature of the section is the remarkable deposition-dip, which rises to as much as 32 degrees. Since 1905 the whole mass of deposits has been slowly cut back westwards, and Mr. Male states that the section was not so good in 1916–17 as when

he first saw it. Since then it has deteriorated still more. On the other hand, the cleavage was better developed than I had ever seen it.

The deposits are banked up against an old Pleistocene cliff of the Caninia oolite (here exceedingly veined with calcite), which is part of the long valley-side feature. Here and there it is vertical, or even slightly undercut. The main floor of the quarry is at about 60 feet O.D., the top of the whole suite of drifts at about 120 feet O.D., so that the depth seen is 60 feet. But in the outer parts of the quarry, 54 yards away from the cliff, where the floor is cut down to about 50 feet, the sand appears again, and above it the

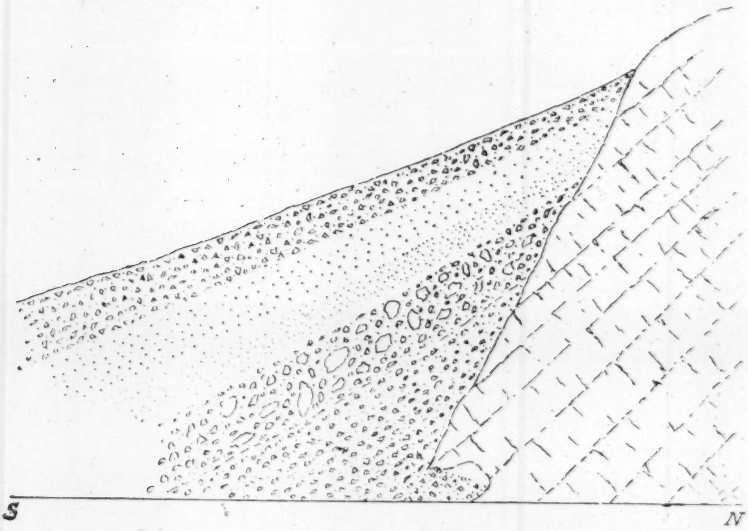


FIG. 3.—The Holly Lane Section. Scale: 1 inch = 27 feet. The base-line is at 60 feet above sea-level. The highest point of the Pleistocene deposit is at 120 feet above sea-level. The deposits shown are in ascending order: Lower breccia, coarse breccia, sandy loam, loamy sand, upper breccia. The cave is shown as when filled with the lower breccia.

upper breccia, which has come down on the dip. The deposits have also been cut back eastwards about 51 yards from the cave, and there we find another good section, but the cliff-brow, and with it the summit of the drifts, has declined, so that the depth seen is only about 20 feet. All is sandy breccia with blocks about 3–4 inches in diameter, save for four lenticular, 1 ft. bands, dipping at about 30 degrees, of loamy sand with cleavage. So far as can now be made out, the fine deposits have here almost wedged out, allowing the upper and lower breccias to coalesce. The crag here overhangs 40 degrees, with sand adhering to the undercut face. The whole mass of drifts dies out rapidly westwards, and has disappeared at

the lane, for, in the large quarry beyond, it does not seem to have existed.

The cave is really about 45 yards north-east of Fig. 3, but is brought artificially into that plane in order to show its relations. Its floor is at about 60 feet O.D., and as no rock is to be seen outside, its door would appear to have been some way up the old steep feature. Its domed roof rises a little above its entrance-arch, and the interior is about 8 feet high and 18 feet wide, penetrating the hill to about 10 feet. It was filled with the lower breccia to within about 1 ft. 6 in. of the roof, and on the floor, below the breccia, were 8–12 inches of a dull red stony loam, described as "cave-earth". Although it has deteriorated, the great western section may improve again, and should be examined from time to time, as the drifts will doubtless, by degrees, be worked away altogether.

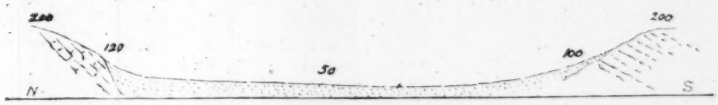


FIG. 4.—Profile of the Vale of Gordano between Holly Lane and Conygar. Scale: 9 inches = 1 mile.

Conygar (Fig. 1).—On the quarry-brows, up to about 180 feet O.D., there is a local breccia of Coal Measure sandstone, with a sandy matrix, above which are 3–4 feet of ruddy, loamy sand. That this is not a mere weathering-product of the sandstone has been shown on p. 368. The sand and breccia can also be seen along the steep quarry cart-road, but the thickness (from rock-outcrops in the woods) does not appear to be great. Stony sand is proved in the gentle slopes below the high road in two shallow sections, and by many molehills, as far as the railway.

East Clevedon Quarry.—This is on the western side of the great gap (Figs. 1, 2), not far up the lane which leads into the woods. A Pleistocene crag of crinoidal *Z* limestones has been revealed, resting against which is a mass of angular local breccia, with 4 to 5 in. blocks in a matrix of ruddy loamy sand. This drift is about 50 feet deep, and climbs up to about 120 feet O.D., the features plainly indicating that the breccia sweeps down the slopes to join the stony sand of the railway cutting. Though the section just reaches the outcrop of the Coal Measures, only one or two blocks of their sandstone has been found in this drift.

East Clevedon Railway Cutting.—This is at about 30–40 feet O.D., just where (west of the church) the gap is opening out into the Vale of Gordano, and is within the outcrop of the Coal Measures. It shows about 6 feet of loamy ruddy sand of typical composition and quite unstratified. The blocks are all of Coal Measure sandstone, save one or two of decayed Caninia limestone from the higher crags.

Gordano Vale Railway Cutting is in the middle of the valley, close

to the 50 ft. contour (Fig. 1), 370–500 yards south by west from the Holly Lane quarry. It is about 170 yards long, and is the best section in the drifts of the valley-floors. About 6 feet of ruddy loamy sand are seen, with a few stones, which are partly Coal Measure sandstone, partly Caninia oolite, the latter being more numerous on the northern side. Not the faintest sign of stratification has been detected even after frost, though the section is still vertical and clear. Heavy minerals are more plentiful than on the hill-flanks, and more facetted quartz was found here than anywhere else.

Highdale.—Early in 1918 the roadwall at the 70 ft. level, between the Fir Wood and the allotments, $\frac{3}{8}$ mile north-east of the station (Fig. 1), collapsed, and clearing for its rebuilding exposed for a while a good section in more than 8 feet of loamy sand. There were some angular blocks of the dolomitic Trias conglomerate which occurs at that spot, and the sand was unstratified. It yielded *Helix aspersa* Müll., the shells, though retaining traces of colour-banding, being decayed and evidently old, and I think *in situ*. No base was visible, and the drifts evidently form the gentle sandy slopes which run down to the alluvium. About 200 yards to the W.S.W., at 80–90 feet O.D., similar sand can be seen clinging to the back of the steep little combe above Highdale Farm; and a little of it is also to be seen 180 yards further south-west, at the west end of Highdale Avenue.

Lower Clevedon.—Major A. B. Trestrail informs me that several feet of loam were cut into when making the bowling-green in Princes Road. Stony sand is visible above sandy slopes near St. John's Church, and several feet of it are said to have been cut into when building a vestry. It is also reported at the foundations of the houses in St. John's Road, and as being banked up to several feet against the east end of Hangstone crag (shown in Fig. 1 by the sharp southward projection in the 50 ft. contour—though the crag just reaches 100 feet in height). That crag, and the quarry in Jesmond Road, are bare; but stony sand reappears between them and Clevedon Hall, passing over the low part of the ridge to the "Green Beach", where, just to the west of the 50 ft. contour, a little sandy loam that seems alien rests on limestone rubble at the cliff's brow. Sandy breccias appear also at the roadside quarry on the southern side of the Old Church Headland.

(*To be continued.*)

REVIEWS.

The Study of Progressive Metamorphism.

(1) V. M. Goldschmidt. Die Kaledonische Deformation der Süd-Norwegischen Urgebirgstafel. Vid. Selsk. Skrifter, M.N.Kl., No. 19, 1912, p. 11.

(2) V. M. Goldschmidt. Die Kalksilikatgneise und Kalksilikatglimmerschiefer des Trondhjemgebiets. Vid. Selsk. Skrifter, M.N.Kl., No. 10, 1915, p. 1.

(3) A. Gavelin. Lecture on the Ruotivare Region. Geol. Fören. Stockh. Förh., vol. xxxvii, 1915, p. 23.

(4) A. Gavelin. Til Frågan om de kristallina seveskiffrarnas ursprung och metamorfos. Geol. Fören. Stockh. Förh., vol. xli, 1919, p. 313.

(5) P. Quensel. De kristalline Sevebergarternas geologiska och petrografiska ställning inom Kebnekaiseområdet. Geol. Fören. Stockh. Förh., vol. xli, 1919, p. 19.

(6) V. M. Goldschmidt. Die Injektionsmetamorphose im Stavanger Gebiete. Vid. Selsk. Skrifter, M.N.Kl., No. 10, 1921, p. 1.

IT is now almost thirty years since Mr. Barrow first unfolded the evidence for progressive metamorphism on a regional scale in the Pre-Cambrian sediments of the South-east Highlands of Scotland. This early publication has been supplemented by a more detailed map in 1912 in the *Proceedings* of the Geologists' Association. Within the last few years comprehensive studies on progressive metamorphism have been made in Scandinavia, with results in many ways identical with those of Barrow. It is unfortunate, however, that the work of Barrow, preceding as it does by more than twenty years the zonal mapping of Scandinavian areas, has remained unknown to Scandinavian petrologists, and, indeed, as the writer has experienced, to German and Swiss petrologists generally.

It is to Goldschmidt, Quensel, and Gavelin that we owe important studies in the Scandinavian region.

The argillaceous sediment has been throughout the principal rock type used in the study of progressive metamorphism.

In the Trondhjem district, Norway, dynamo-thermal zones have been mapped in the Palæozoic sediments, and the succession, as denoted by the first appearance of indicator minerals, is chlorite, biotite, garnet, the chlorite zone corresponding to Barrow's zone of digested clastic mica. Higher zones undoubtedly exist in this area, but no further subdivision of the garnet zone has yet been published. In the Stavanger district the zones in the Cambro-Ordovician phyllites are chlorite, garnet, biotite, the normal biotite garnet order being here inverted. The reason for this inversion is clearly the composition of the garnet, not a true almandine as analyses show, but one rich in the spessartine molecule. [The same inversion

appears in the metamorphosed rocks of the Start, South Devon (*Proc. Geol. Soc.*, 1922, pp. 88–9).]

Rocks containing the typical minerals of Barrow's higher zones are not absent from the Stavanger region, but their occurrence is sporadic. Superposed on this progressive metamorphism is an intensive soda metasomatism in the neighbourhood of the sodic Caledonian intrusives (trondhjemites, etc.), the garnet zone thus passing into a zone of albite-porphyroblast-schists, and these in turn to injection gneisses. There is evidence to believe that the soda has been here introduced not as albite, but as sodium silicate (water glass), which, reacting with the aluminous constituents, has given rise to abundant albite.

To the writer it appears that herein lies the reason for the irregular occurrence of Barrow's higher zones, the formation of staurolite, kyanite, and sillimanite being largely inhibited by reaction of the excess alumina with the incoming soda from the intrusives. The first published report of intensive metasomatism in the contact zones of intrusives comes, however, from the Kvikkjokk and Kebnekaise regions of northern Sweden, as studied by Gavelin and Quensel. A preliminary report appeared in 1915, but the detailed work of Quensel has still to be published.

This further work of Quensel, and the continuation of Goldschmidt's work in the Stavanger region, particularly in regard to the evidence of progressive metamorphism in the green schists of this area, will be awaited with much interest.

The results already obtained point clearly to the need for a careful study of those Highland sediments in contact with the older and newer granites, particularly any of sodic character, for evidence of metasomatic processes of a like order.

Whatever be the case, it is clear that in Barrow's zonal map of the south-east Highlands we have the most complete and detailed of any yet published.

C. E. Tilley.

Geological Work on the Western Front. The Work of the Royal Engineers in the European War, 1914–1919. pp. viii + 71, with vii plates and 19 figures, photographs, maps, and sections. Chatham: W. J. Mackay & Co., Ltd., 1922.

THIS book, of which, we believe, a very limited issue was printed, is published by the Secretary of the Institution of Royal Engineers, Chatham. It contains a record of the geological work carried out in France and Belgium by the geologists attached to the military forces. In April, 1915, Captain W. B. R. King, of H.M. Geological Survey, was chosen for this work, and in June he joined the staff of the Chief Engineer in France, under whom he continued to work till the end of the war. In May, 1916, Lieut.-Col. Sir T. W. Edgeworth David arrived in France with the Australian Mining Corps, and acted at first as geological adviser on

mines to the First, Second, and Third Armies. In September, 1916, he became general geological adviser on mining matters at G.H.Q. These two officers, with Lieut. Loftus Hills, of the Tasmanian Survey, and two other Australian tunnelling officers, formed the whole geological staff up to the Armistice. It is to be noted that from April, 1915, to May, 1916, Captain King was the only official geologist on the whole Western Front.

The book before us contains an excellent and interesting account of different kinds of work carried out by these officers, under the general headings of Water Supply, Mining, Field Positions, Road Metal, Concrete, Coal Mines, Dug-outs, and others. The importance of water supply to an army is obvious, and this subject is well dealt with here. This should be read in connexion with Captain King's paper in the *Geographical Journal* for October, 1919. Both in mining and in the construction of dug-outs one of the most important points is the avoidance of water-bearing strata and a knowledge of the position of the water-table at different times of the year. Much information is also given as to boring plants adapted for test-bores for these special purposes. Another interesting and unusual subject here dealt with is the effect of shell-holes on the superficial deposits of areas where it was desired to put down a barrage in order to ascertain whether the barrage would stop our own advance by rendering the surface impossibly wet and full of water-holes. For this and innumerable other purposes geological maps were needed, and much valuable help was received from French and Belgian geologists.

In conclusion some particulars are given of the geological establishments of the German and American armies, and a suggestion is drawn up for an adequate British geological staff, R.E., in any future war. The total personnel suggested for G.H.Q. and five armies numbers twenty-seven. Although it is not considered necessary to maintain a regular geological staff in peace time, yet facilities should exist, by keeping touch with H.M. Geological Survey, to bring such an organization into existence at the shortest notice in any emergency, since the existence of an adequate geological staff from the beginning of any war would be the means of saving much life, labour, and expense.

We rejoice that this book has been published as a permanent record of the brilliant work performed by the British geologists on the Western Front.

Eocene Mollusca from Nigeria. By R. B. Newton. Bull. 3, Geol. Survey of Nigeria. pp. 148, with a Map and 11 Plates. Published by the Nigerian Government, 1922. Price 17*s.* 6*d.* net.

THIS forms a general account of several collections made during 1914 to 1917 from Ameki, about 60 miles north-west of Calabar. A Zeuglodont, leathery turtle, and carinate bird from this deposit have already been described by Dr. Andrews, some fish remains by

Dr. Smith Woodward, and some foraminifera are included in this paper as an appendix by Heron-Allen and Earland.

Mr. Newton, while formerly laying stress on the similarity of the fauna to the Claiborne, Mokattam, and European Middle-Eocene, has now, after further study, come to regard this as an Upper Lutetian stage, recognizing at the same time the Bartonian facies of the material. The Mollusca are extremely well preserved, and have been reproduced from the excellent photographs of Mr. P. Dollman. Mr. A. E. Kitson and Dr. J. D. Falconer must be congratulated on securing the publication of so interesting a collection, which forms a valuable addition to our knowledge of the geology of this part of West Africa.

On the Eastern Part of the Arctic Basalt Plateau. By H. G. Backlund. Meddelanden från Åbo Akademis Geologisk-Mineralogiska Institut, No. 1. pp. 53, with 2 text-figures. Åbo, 1920.

OUR knowledge of the great basalt plateaus of Siberia is very slight in comparison with the great amount of detail available as to the western and extreme northern parts of the Arctic Province. The paper now under review is a most tantalizing production, since the author states that he had in his possession material from regions covering the whole of the eastern area, hinting darkly at a mysterious accident which deprived him of almost all his specimens and notes. After this catastrophe he decided to publish a detailed account of the small amount that remained. Full descriptions are given of three specimens, one from Bennett Island in the extreme north of the New Siberian Islands, and one from Wilkitski Island, to the east of the same group; the third specimen examined in detail came from the Adzra river, in the Petchora region, west of the Urals. The first-named proves to be an olivine-trachydolerite, the second a basaltoid nephelinite, and the third a basalt very like a type described from Spitsbergen, and of the normal Brito-Arctic facies. From these results, and from the author's general knowledge of the eastern plateau, it is concluded that the rock-types found are very similar to those of the western and northern areas from Spitsbergen to Britain, namely, for the most part normal basalts and olivine-basalts, with an occasional local lapse into alkaline types.

The physiographic relations of the Siberian basalts are peculiar; the lava-flows only occur in deeply eroded valleys, which they partly fill. Apparently the fissures never opened as high as the general plateau surface, which consists of sedimentary rocks. The extrusion of the lavas is correlated with isostatic continental uplift on a large scale. Unfortunately, in the concluding and most interesting sections of the paper, the author's English becomes somewhat obscure, and some of his points are difficult to follow; he seems to consider, however, that in addition to isostatic adjustment some form of

magmatic pressure is necessary to account for the phenomena observed, and that molten magma may exert even more force than admitted by Gilbert in his laccolithic theory, though not so much as formerly supposed by von Buch and his followers.

R. H. R.

REPORTS AND PROCEEDINGS.

GEOLOGISTS' ASSOCIATION.

9th June, 1922.

"The Liassic Rocks of Glamorgan." By A. E. Trueman, D.Sc., F.G.S., University College of Swansea.

The Liassic rocks of Glamorgan occur in several small outliers near Cardiff and in a broad tract stretching between Bridgend and Cowbridge, and southwards to the sea. This area is known as the Vale of Glamorgan. In a previous communication the Liassic outliers near Cardiff were described (*Proc. Geol. Assoc.*, xxxi, 1920, p. 93). In the present paper an account is given of the zonal succession in the larger area; only the lowest zones of the Lower Lias are represented (*planorbis-semicostatus*), but these are unusually thick (350 feet) and several subdivisions are recognized. Particular attention is drawn to the gryphæate lamellibranchs of these zones and to their use in correlation.

In the west of the area the Lias is often of littoral character; the littoral deposits accumulated near the shores of several small islands, mainly of Carboniferous Limestone. These deposits are best exposed in the cliffs near Southerndown and Dunraven. The relations of the littoral deposits to the normal Lias limestones and shales are discussed and consideration is given to the physical conditions under which the rocks were laid down.

The paper includes petrological notes on the limestones and conglomerates, and notes on some of the ammonites.

"The Recession of the Chalk Escarpment and the development of Valleys in the Chalk between the Mole and the Darenth." By C. C. Fagg, F.G.S.

Contrast in altitude and features of Chalk area east and west of the Brighton Road. Gaps and passes in the North Downs. Some significant sections. The water-table in the Chalk. Springs and Bourneflows. The Gault outcrop as the decisive factor. Its former extension southward and upward. Mole Gap and Kenley Valley becoming dry. Recent landmarks in recession of escarpment—Limpsfield Gravel—(500 feet, Acheulian). Passes at Merstham, Godstone, and Pebble-Combe. Relation of these to *fluviatile* erosion of "Dry" valleys. Valleys not all of same age. Variety of stones on the Chalk Plateau and their significance. Position of Tertiary escarpment at Worms Heath and Woodmansterne at close of Pliocene. Possible evidence of present flora of the district.

Critical review of other hypotheses for formation of Chalk Valleys.

Mineralogical Society.

27th June.—Dr. A. Hutchinson, President, in the chair.

A. Brammall and H. F. Harwood: The Dartmoor Granite; its Accessory Minerals and Petrology.

Minerals of general occurrence—tourmaline, ilmenite, magnetite, apatite, monazite, garnet, zircon—(1) in water clear, small crystals, (2) in tawny, zoned, larger, and more abundant crystals, pyrites and pyrrhotite. More restricted: fluor (colourless, blue, and purple), topaz, cassiterite, andalusite, sphene, anatase, barytes. Biotite is abundant; muscovite is scanty. Streams have yielded, in addition, rutile, brookite, and blue-green anatase. Analyses are given of granite types (bulk), biotite, porphyritic felspars (baryta-bearing), and some accessory minerals. The Tor area (Haytor–Widecombe) is mapped, to show that the granite occurs as successive shoots or flows, differing appreciably in chemical composition. Texture becomes coarser, porphyritic felspars become more abundant and richer in plagioclase content, percentage of biotite and accessories increases with vertical descent in a flow. The relationship of topography to pseudo-bedding, jointing, veining, and probable faulting is discussed.

W. F. P. McLintock and F. R. Ennos: On the structure and composition of the Strathmore meteorite.

A description is given of the microscopical characters as seen in thin sections of this meteorite, stones of which fell in Perthshire and Forfarshire on 3rd December, 1917. The structure is that of the intermediate chondrite group (C i). An apatite-like mineral is present. Detailed chemical analyses of the magnetic and non-magnetic portions agree closely with the Baroti group.

Henry F. Collins: On some crystallized sulphates from the province of Huelva, Spain.

Analyses are given of pisanite, chalcanthite, coquimbite, copiapite, voltaite, roemerite, etc., from various pyrites mines. Experiments were made to determine the range of miscibility of iron sulphate and copper sulphate in mixed crystals of pisanite ($R''SO_4.7H_2O$) and chalcanthite ($R''SO_4.5H_2O$).

Harold Hilton: The graphical construction of the constants of a shear.

A graphical construction, based on the gnomonic projection, is given for obtaining the two circular planes of a shear, when the initial and final positions of two crystal-poles or edges are known.

Harold Hilton: A note on crystallographic notation.

A notation is suggested for the thirty-two crystal-classes and the 230 groups of movements, which is easy to write and print, and is based on the fundamental principles of structure-theory.

A. F. Hallimond (with chemical analysis by E. G. Radley): On glauconite from the Greensand near Lewes, Sussex: the constitution of glauconite.

A boring through 325 feet of Gault at Iford Manor yielded glauconite sand. A discussion of the analysis of this material and of some previously published analyses leads to the formula $R_2O.(1R_2O_3.RO).10SiO_2.nH_2O$.

L. J. SPENCER: Ninth list of new mineral names.

CORRESPONDENCE.

GAULT AND LOWER GREENSAND NEAR LEIGHTON BUZZARD.

SIR,—I have just had the pleasure of reading Mr. G. W. Lamplugh's paper on the Junction of the Gault and Lower Greensand near Leighton Buzzard (*Quart. Journ. Geol. Soc.*, vol. lxxviii, 1922). Side by side with it I have Dr. Kitchin and Mr. Pringle's paper on the same area (GEOL. MAG., vol. lvii, 1920). Both papers are convincingly written, but obviously the data relied upon by one or other authority must be misleading. May I be permitted to call attention to one or two points which forcibly strike an unbiassed reader? It seems obvious that one has to face in the case of the Shenley Hill Limestone the problems of a "facies fauna". Both sides admit the anomalous character of the deposit whether it is regarded as infra-Gault Clay or as Cenomanian. Moreover, both sides make repeated references to the "continental Tourtias", especially of "Flanders". Mr. Lamplugh likens the Ironstone-breccia of the Chamberlain Barn section to a Tourtia (p. 61). Personally, I cannot recall a Tourtia which answers to the description given of the Breccia. Mr. Lamplugh also remarks: "Correlation with the Tourtias is useless for any narrow and critical demarcation of age, since the Tourtias are known to occur at different horizons where actually intercalated in the Cretaceous sequence; and, where they form the base of that sequence and rest directly on the much older rocks, they are 'condensed' deposits, probably covering a long period, and they then generally contain many fossils not known to occur in beds which lie above the Gault where it is actually present" (p. 75). Sir, in the interests of the sanity of British geology I ask, are these "Tourtias" to be dismissed in this scanty fashion? But a few hours' journey from our own shores one may study a whole succession of "Tourtias", ranging in age from Albian to highest Cenomanian, and even to Turonian and Senonian, the age of which can be relatively and, in most cases, precisely fixed.

In their recent paper on "The Overlap of the Upper Gault in England" (GEOL. MAG., vol. lix, April–May, 1922), Messrs. Kitchin and Pringle remark: "In any attempt to determine the zonal relationships when studying deposits of clay such as the Gault, subject to lateral change to other types of sedimentation, we must be prepared to pin our faith entirely to the fossils. There remains, of course, the recognition of the species appropriate for such an important use and the power to apply this evidence legitimately,